FAIR HEARINGS
APPENDICES

MOMA
Medicaid Orthodontists of Massachusetts Association

DR. MOUHAB Z RIZKALLAH DDS MSD CAGS

TABLE OF APPENDICES

COMMONWEALTH OF MASSACHUSETTS

MIDDLESEX, ss.

SUPERIOR COURT
CIVIL ACTION
No. 2081CV01893

DAYANNE N. & others[1]

vs.

CHARLES BAKER, GOVERNOR & others[2]

DECISION AND ORDER ON PLAINTIFFS' MOTION FOR INJUNCTIVE RELIEF

Dayanne N., Natalya M., Aslyn P., Charmaine C., and Ana R. ("child plaintiffs"), along with the Medicaid Orthodontists of Massachusetts Association, Inc. ("MOMA") (collectively with child plaintiffs, "plaintiffs"), filed this action against Charles Baker, Governor of Massachusetts; Marylou Sudders, Secretary of the Executive Office of Health and Human Services; and Daniel Tsai, Assistant Secretary for MassHealth (collectively, "EOHHS") concerning changes to MassHealth's authorization process, which allegedly restricts coverage for child and youth orthodontic treatment. The matter is presently before the court on the plaintiffs' motion for a preliminary injunction, pursuant to Mass. R. Civ. P. 65, seeking to enjoin the EOHHS from: (1) denying coverage to eligible children and youth based on the purported unlawful changes to the authorization process; and (2) eliminating the Peer-to-Peer Review process, which previously allowed providers to challenge incorrectly denied authorizations for orthodontic coverage. After hearing and review of all materials submitted, including those which have been impounded, the plaintiffs' motion is **ALLOWED** in part and **DENIED** in part for the following reasons.

[1] Natalya M., Aslyn P., Charmaine C., and Ana R., on behalf of themselves and all others similarly situated; and Medicaid Orthodontists of Massachusetts Association, Inc.
[2] Marylou Sudders, Secretary of the Executive Office of Health and Human Services; and Daniel Tsai, Assistant Secretary for MassHealth.

FACTUAL BACKGROUND

The record before the court, consisting of the verified complaint, exhibits thereto, and affidavits, provides the following factual background.[3] Additional facts are reserved for discussion below.

A. MassHealth Medicaid Program

The Medicaid program, authorized by Title XIX of the Social Security Act, is a voluntary, cooperative federal and state program, which provides medical services for low-income persons. See 42 U.S.C. §§ 1396 et seq. If a state chooses to participate in the program, it must comply with requirements imposed by the Medicaid statutes and by the Secretary of Health and Human Services. One of the requirements is that participating states must cover Early and Periodic Screening, Diagnostic and Treatment ("EPSDT") for Medicaid-eligible children under age twenty-one. 42 U.S.C. §§ 1396a(a)(10)(A), 1396a(a)(43), 1396d(a)(4)(B), 1396d(r). EPSDT includes dental services for "relief of pain and infections, restoration of teeth, and maintenance of dental health." 42 U.S.C. § 1396d(r)(3)(B).

Massachusetts participates in the Medicaid program via the establishment of MassHealth, statutorily known as the Division of Medical Assistance. G. L. c. 118E, § 9. It is an agency of the EOHHS, and DentaQuest is the third-party subcontractor that runs the MassHealth dental program pursuant to a contract with the EOHHS.

MassHealth must provide EPSDT "in accordance with reasonable standards of medical and dental practice determined by the agency after consultation with recognized medical and dental organizations involved in child health care." 42 C.F.R. § 441.56(b)(2). All medically

[3] The Massachusetts Law Reform Institute submitted a brief as amicus curiae in support of the plaintiffs' motion for a preliminary injunction.

necessary services must meet professionally recognized standards of health care. 130 Code Mass. Regs. § 450.204(B).

B. Coverage for Orthodontic Care and the HLD Index

MassHealth covers certain dental services, including orthodontic treatment, subject to prior authorization, once per member per lifetime before age twenty-one if the care is medically necessary. 130 Code Mass. Regs. § 420.431(C)(3). A provider submitting a prior authorization request for orthodontic services must include appropriate and sufficient documentation to justify the medical necessity for the service. 130 Code Mass. Regs. § 420.410(C)(1). Orthodontic treatment is medically necessary when a child's teeth are so badly misaligned (maloccluded) that it constitutes a handicap (handicapping malocclusion). 130 Code Mass. Regs. § 420.431(C)(3). MassHealth determines whether a malocclusion is handicapping based on clinical standards for medical necessity as provided in Appendix D of the MassHealth Dental Manual. Id. Appendix D is a form called the Handicapping Labio-Lingual Deviations Index ("HLD form" or "HLD Index"), which serves as the screening tool, i.e., the prior authorization, to determine whether MassHealth will cover treatment.

The HLD form contains detailed instructions on how to take measurements and score a child's condition. To complete the HLD form, the orthodontist examines the child and takes diagnostic measurements, photographs, and x-rays. The HLD Index then assigns scores for various dental conditions, and if the sum of the scores is high enough, MassHealth provides coverage for treatment.[4] If the sum of the scores is not high enough, MassHealth denies coverage. Where a patient does not meet the threshold score on the HLD Index, a provider can submit a medical necessity narrative with supporting documentation to demonstrate why

[4] There are certain conditions that automatically qualify as a handicapping malocclusion.

treatment is medically necessary. If the prior authorization is denied, the provider can submit an online request for reconsideration of the decision. Generally, a dental reviewer who is different than the original reviewer conducts the reconsideration.[5]

Until recently, the diagnostic instructions were consistent with national standards. However, on March 25, 2020, MassHealth changed the scoring instructions on the HLD Index via Transmittal Letter DEN-104, and again, on June 26, 2020, via Transmittal Letter DEN-106 (collectively, "Transmittal Letters"). These changes were promulgated without notice or a public hearing.[6]

Although MassHealth referred to the changes as a "clarification," the plaintiffs claim that these new standards are more restrictive than the prior instructions, and as a result, it has caused hundreds of children, including the child plaintiffs, who previously were eligible to become ineligible for orthodontic treatment.[7] The plaintiffs also claim that most of the changes are a departure from professionally recognized standards of care, and as such, most providers feel they are unable to certify the current HLD form under the pains and penalties of perjury, as is required. Consequently, the plaintiffs claim, these changes have virtually foreclosed MassHealth members' access to orthodontic care across the state.

The plaintiffs also allege that MassHealth was aware that these changes were not "technical edits" or a clarification of standards, because on May 21, 2018, Tracy Gilman Chase ("Chase"), the Regional Director of DentaQuest, sent her supervisor, James E. Thommes ("Thommes"), DentaQuest's Vice President of Clinical Management, an email inquiring about

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[5] MassHealth members also may request a fair hearing to appeal the denial of a prior authorization. 130 Code Mass. Regs. §§ 610.012(A), 610.031(A), 610.032(A)(1).

[6] For the sake of brevity, the court will not list the changes to the instructions; however, they are set forth in the Complaint.

[7] MOMA's board of directors estimate that sixty percent of children, who were eligible previously, no longer meet the HLD Index threshold for coverage.

the effect of these changes. Thommes stated, "Approvals . . . would drop," and "[e]xpect significant noise."

C. Peer-to-Peer Review Process

Several years ago, MassHealth promulgated rules that allowed providers to challenge incorrectly denied authorizations for orthodontic coverage. The rules regarding the Peer-to-Peer Review process are set forth in MassHealth's Office Reference Manual. Through the establishment of this process, providers can appeal denials on their patients' behalf by conferring over the phone with MassHealth orthodontic consultants and pointing out conditions that were missed or overlooked. The plaintiffs allege that between 2014 and 2019, one doctor in particular, Dr. Mouhab Z. Rizkallah ("Dr. Rizkallah"), had 62% of initially denied cases overturned via the Peer-to-Peer Review. Because such a high number of denials are overturned, the plaintiffs argue that the Peer-to-Peer Review process is critical to protecting patients' rights.

On April 27, 2020, MassHealth notified providers via email that as of May 1, 2020, MassHealth would no longer offer Peer-to-Peer Review. Rather, requests for reconsideration must be submitted through the online portal or via a patient's request for a fair hearing.

D. Claims

The plaintiffs have asserted six claims. Count 1 alleges that the defendants violated the plaintiffs' civil rights pursuant to 42 U.S.C. § 1983 as well as the plaintiffs' rights under the Medicaid EPSDT statutes by denying coverage for orthodontic services. Count 2 alleges that the defendants violated the Administrative Procedures Act, G. L. c. 30A, § 2, by failing to comply with the notice and hearing requirements before promulgating the Transmittal Letters and eliminating the Peer-to-Peer Review process. Count 3 asserts a claim of unlawful discrimination under G. L. c. 151B, § 4(10). Count 4 seeks to enjoin the EOHHS from enforcing the

Transmittal Letters. Count 5 asserts a due process violation under 42 U.S.C. § 1396a(a)(3). Finally, Count 6 asserts a claim for declaratory relief, in which the plaintiffs seek a declaration of their rights under the relevant Medicaid statutes.

DISCUSSION

The plaintiffs seek a preliminary injunction pursuant to Mass. R. Civ. P. 65, alleging that the defendants failed to comply with the notice and hearing requirements set forth in G. L. c. 30A, § 2 and G. L. c. 118E, § 12 before issuing the Transmittal Letters and eliminating the Peer-to-Peer Review program. As such, the plaintiffs seek to enjoin the EOHHS from: (1) withholding prior authorization for comprehensive orthodontic treatment to eligible children and youth based on the new criteria and instructions set forth in the Transmittal Letters; and (2) eliminating the Peer-to-Peer Review appeal process. Because the plaintiffs' preliminary injunction request implicates Count 2 (violation of G. L. c. 30A, § 2 and G. L. c. 118E, § 12), the court will limit its discussion to that claim.[8]

A. Standard of Review

Under the well-known standard for granting a preliminary injunction, the plaintiffs must show that they are likely to succeed on the merits and that in the absence of an injunction they will suffer irreparable harm sufficient to outweigh the harm that an erroneous injunction would impose on the defendants. GTE Prods. Corp. v. Stewart, 414 Mass. 721, 722-723 (1993); Packaging Indus. Grp., Inc. v. Cheney, 380 Mass. 609, 617 (1980). Where, as here, the plaintiffs seek to enjoin governmental action, the court must also determine if the relief requested promotes the public interest or, alternatively, will not adversely affect the public.

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[8] The motion also implicates the plaintiffs' civil rights claim (Count 1), but because the plaintiffs are entitled to the relief requested with respect to their Administrative Procedures Act claim (Count 2), the court need not discuss Count 1.

Commonwealth v. Mass. CRINC, 392 Mass. 79, 89 (1984). A preliminary injunction is a significant remedy that should not be granted unless the plaintiffs have made a clear showing of entitlement thereto. Student No. 9 v. Board of Educ., 440 Mass. 752, 762 (2004). In balancing these factors, the court considers not so much "the raw amount of irreparable harm the party might conceivably suffer, but rather the risk of such harm in light of the party's chance of success on the merits. Only where the balance between these risks cuts in favor of the moving party may a preliminary injunction properly issue." Packaging Indus. Grp., Inc., 380 Mass. at 617.

B. Analysis

Pursuant to G. L. c. 118E, § 12, MassHealth may adopt, promulgate, amend, and rescind rules and regulations that are suitable or necessary to carry out the provisions relating to the utilization of and payment for care and services available under the state's Medicaid plan. "Rules and regulations which restrict eligibility or covered services require a public hearing under section 2 of chapter 30A ["Section 2"]." Id. Section 2 also requires certain notices to be sent prior to the hearing. The crucial question presently before the court is whether the Transmittal Letters and the elimination of the Peer-to-Peer Review program constitute regulations that restrict eligibility or covered services, such that they are subject to the notice and hearing requirements in Section 2 and G. L. c. 118E, § 12.

Under the Administrative Procedures Act ("APA"), see G. L. c. 30A, §§ 1-25, "a regulation 'includes the whole or any part of every rule, regulation, standard or other requirement of general application and future effect, including the amendment or repeal thereof, adopted by an agency to implement or interpret the law enforced or administered by it.'" Carey v. Commission of Corr., 479 Mass. 367, 371 (2018), quoting G. L. c. 30A, § 1(5). Given the purpose of the APA, courts interpret the definition of regulation broadly.[9] Id. "Nevertheless, the definition excludes 'regulations concerning only the internal management of the agency . . . and not substantially affecting the rights of or the procedures available to the public or that portion of the public affected by the agency's activities" [alterations omitted].[10] Id. at 371-372; quoting G. L. c. 30A, § 1(5)(b).

Here, the evidence weighs in the plaintiffs' favor that the Transmittal Letters, which changed the instructions and criteria on the HLD Index, substantially affected the rights available to MassHealth members. According to Dr. Rizkallah's affidavit, the new scoring instructions and criteria severely restrict coverage. In fact, MOMA estimates that sixty percent of children who previously qualified as having a medical necessity for orthodontic treatment no longer qualify. Although the defendants argue that the instructional changes were merely technical edits and clarifications and were "intended to fill in the details or clear up an ambiguity of an established policy," the court is not persuaded. Massachusetts Gen. Hosp. v. Rate Setting Comm'n, 371 Mass. 705, 707 (1977).

By the defendants' own admission in an email on May 21, 2018 from Thommes to Chase, the defendants were aware that the instructional changes would cause approvals to drop. However, "eligibility requirements can only be accomplished through the promulgation of rules since . . . [they] substantially affect the rights of the regulated parties." Trust Ins. Co. v. Commissioner of the Div. of Ins., 1997 Mass. Super. LEXIS 344 at *11 (Mass. Super. 1997). As a result, changes to eligibility requirements must be implemented in accordance with pertinent

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[9] Although courts accord substantial deference to an agency's interpretation of its own regulations, courts do not defer to an agency's interpretation of the APA. Carey, 479 Mass. at 371.

[10] Regulations concerning the internal management of an agency are "those that concern the organizational structure of [the] agency . . . or those that are directed toward agency employees, instructing them on how they should perform their duties." Carey, 479 Mass. at 372. The regulations at issue in this case do not concern the internal management of MassHealth.

rulemaking requirements, such as the notice and public hearing requirements set forth in Section 2 and G. L. c. 118E, § 12.

The defendants, nonetheless, argue that the child plaintiffs cannot meet their burden because their providers failed to complete the medical necessity narrative portion on their HLD forms and because the child plaintiffs failed to exhaust their administrative remedies by failing to request a fair hearing. According to Dr. Rizkallah, the medical necessity narrative portion on the HLD form is rarely used by providers and rarely approved – under 1% of the time. Therefore, although this is an alternative basis for approving treatment, the lack of utilization and significantly low approval rate suggests that it is not a viable process for obtaining prior authorization. Additionally, although the child plaintiffs did not request a fair hearing to appeal their denials, it seems that pursuit of a fair hearing would have been fruitless in light of the new eligibility criteria. Accordingly, the court concludes that the plaintiffs have demonstrated a likelihood of succeeding in establishing that the promulgation of the Transmittal Letters are not exempt from the APA notice and hearing requirements and that the defendants failed to comply with same.[11]

As for the elimination of the Peer-to-Peer Review program, based on the competing facts and applicable regulations, the court concludes that the plaintiffs cannot meet their burden of demonstrating a likelihood of success in establishing that the elimination of the telephone review program substantially affects the rights of or procedures available to MassHealth members. See Carey, 479 Mass. at 371. The Peer-to-Peer Review program is not codified in any statute or

[11] The defendants also argue that the plaintiffs lack standing, and thus, the complaint should be dismissed. However, as stated during the motion hearing, the court will entertain the defendants' motion to dismiss at a later date. Nevertheless, the court has reviewed and considered the defendants' arguments in connection with the plaintiffs' burden in demonstrating a likelihood of success on the merits and finds them to be unavailing at this juncture.

regulation. Moreover, even with the elimination of the program, there are two alternative ways in which MassHealth members can challenge denials of prior authorizations. Providers can submit an online request for reconsideration or MassHealth members can request a fair hearing to appeal a decision. 130 Code Mass. Regs. §§ 610.001(a), 610.012. Dr. Rizkallah avers that the success rate for the Peer-to-Peer Review program significantly outweighs the success rate for online requests for reconsideration. While this may be an important consideration for the fact finder at trial, for the purposes of the present motion, the court is not persuaded that this one factor satisfies the plaintiffs' initial burden. Accordingly, the plaintiffs are not entitled to preliminary injunctive relief with respect to the elimination of the Peer-to-Peer Review program.

Turning to the remaining considerations of the preliminary injunction standard, the court concludes that in the absence of an injunction the plaintiffs will suffer irreparable harm sufficient to outweigh the harm that an erroneous injunction would impose on the defendants. GTE Prods. Corp., 414 Mass. at 722-723. The irreparable harm that will result to the child plaintiffs in the absence of an injunction is evident. The children allegedly are suffering from developmental harm and no longer have access to proper treatment in light of the new eligibility requirements on the HLD Index. Their situation is further complicated by the fact that they are only eligible for orthodontic treatment until age twenty-one, and at least one of the child plaintiffs is at risk of aging out of the system. See Massachusetts Ass'n of Older Ams. v. Sharp, 700 F.2d 749, 753 (1st Cir. 1983) ("Termination of benefits that causes individuals to forego such necessary medical care is clearly irreparable injury."). Moreover, the balance of harms weighs in the plaintiffs' favor. The potential harm to the child plaintiffs outweighs the state's potential budgetary concerns, especially given that the defendants likely violated state law (i.e., the APA). See, e.g., Bontrager v. Indiana Family & Soc. Servs. Admin., 697 F.3d 604, 611 (7th Cir. 2012), and cases cited. Finally, the public interest mirrors factors already considered above. The public interest lies with safeguarding public health rather than any potential budgetary interest the state may have. See, e.g., Pashby v. Delia, 709 F.3d 307, 331 (4th Cir. 2013) ("[T]here is a robust public interest in safeguarding access to health care for those eligible for Medicaid" [citation omitted]).

Accordingly, the court concludes that the plaintiffs have met their burden in proving an entitlement to the preliminary injunctive relief requested with respect to the new instructions in the Transmittal Letters.

ORDER

For the foregoing reasons, it is hereby **ORDERED** that the plaintiffs' motion for preliminary injunction is **ALLOWED** with respect to the new criteria set forth in the Transmittal Letters, and is **DENIED** with respect to the Peer-to-Peer Review program.

It is further **ORDERED** that the defendants are preliminary enjoined from implementing the changes to the scoring instructions on the HLD Index set forth in Transmittal Letters DEN-104 and DEN-106 unless and until they comply with the notice and a public hearing requirements of G. L. c. 30A, § 2 and G. L. c. 118E, § 12.

Camille F. Sarrouf, Jr., Justice
Massachusetts Superior Court

December 14, 2020

COMMONWEALTH OF MASSACHUSETTS

MIDDLESEX, ss. SUPERIOR COURT
C.A. NO. 2081CV01893

DAYANNE N. et al.,

Plaintiffs,

v.

CHARLES BAKER, Governor, et al.,

Defendants.

DEFENDANTS' MEMORANDUM IN OPPOSITION
TO PLAINTIFFS' MOTION FOR PRELIMINARY INJUNCTION
AND IN SUPPORT OF DEFENDANTS' EMERGENCY MOTION TO DISMISS

Douglas S. Martland (BBO# 662248)
David R. Marks (BBO# 548982)
Assistant Attorneys General
One Ashburton Place, Boston, MA 02108
(617) 963-2062/2362
douglas.martland@mass.gov
david.marks@mass.gov

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INTRODUCTION

This case is about the instructions for MassHealth's "prior authorization" process for comprehensive orthodontic treatment. In accordance with federal law, MassHealth requires providers to seek prior authorization from MassHealth before providing comprehensive orthodontic treatment to MassHealth members. A provider submitting a request must include "sufficient documentation to justify the medical necessity for the service," which, for comprehensive orthodontic treatment, means establishing that the member has a "handicapping malocclusion." (This is to be contrasted with a malocclusion that is purely cosmetic, for which orthodontic treatment is not a medical necessity and for which Medicaid does not pay.)

MassHealth uses the HLD Index Form to administer the prior authorization process for orthodontic treatment. (HLD stands for "handicapping labio-lingual deviations.") This sub-regulatory form, explicitly envisioned and described in 130 C.M.R. § 420.431(C)(3), gives providers three alternative methods to establish that a member has a medical need for orthodontic treatment. First, the provider may show that the member has one of seven conditions that automatically qualifies the member for treatment, each of which alone constitutes a "handicapping malocclusion." Second, the provider may score the member based on several measurements, with a score of 22 or more automatically qualifying the member for treatment. Finally, the provider may submit a medical necessity narrative, with accompanying detail and documentation, explaining why treatment is medically necessary to treat the member's handicapping malocclusion even though the patient might not have qualified under the first two methods. If MassHealth's third-party administrator ultimately determines that the provider's showing on all three prongs is inadequate, MassHealth denies the prior authorization and the member has a right to an administrative hearing, followed by judicial review under G.L. c. 30A.

According to the complaint's allegations, unidentified orthodontists sought prior authorization from MassHealth to provide comprehensive orthodontic treatment to five named child plaintiffs. MassHealth's third-party provider denied the prior authorization requests as to each child. Although neither the prior authorization requests nor the notices of denial are attached as exhibits to the complaint, the child plaintiffs, accompanied by an associational plaintiff, attribute the denials to technical modifications MassHealth made to the instructions that accompany the HLD Index Form in March and June of this year. They claim that these technical changes amount to an impermissible restriction on comprehensive orthodontic treatment, that such restrictions can only be accomplished via regulation, and therefore that MassHealth's current HLD Index Form (with the instructions) should be enjoined.

This Court should deny plaintiffs' preliminary injunction motion, and instead dismiss the complaint, because they lack standing. The children lack standing because there are no allegations in the complaint that they have handicapping malocclusions that make comprehensive orthodontic treatment medically necessary under MassHealth regulations, that their alleged injuries are the direct result a specific change to the instructions, that they separately completed all three aspects of the HLD Index Form (including the medical necessity narrative), or that they exhausted available administrative remedies after the prior authorization denials. The association lacks standing because it has failed to establish that its members have individual standing to bring these claims on their own behalf. And even if plaintiffs establish standing, their claims should be dismissed for failure to state a claim for the reasons set forth below.

BACKGROUND

Relevant Requirements of a State Plan for Medical Assistance

A state plan for medical assistance must define eligible persons and the specific services covered by the plan. 42 U.S.C. § 1396a(a)(10), (17). It must provide EPSDT services for Medicaid-eligible individuals under the age of 21. It must also provide for (1) informing all such persons of the availability of EPSDT services, as described in 42 U.S.C. § 1396d(r); (2) provide or arrange for such screening services in all cases where requested; (3) arrange for necessary corrective treatment identified by such child health screening services; and (4) annually report to the federal government certain EPSDT utilization data. 42 U.S.C. § 1396a(a)(43).

EPSDT services must include dental services "(i) at intervals which meet reasonable standards of dental practice, as determined by the State after consultation with recognized dental organizations involved in child health care, and (ii) at such other intervals, indicated as medically necessary, to determine the existence of a suspected illness or condition." 42 U.S.C. § 1396d(r)(3). These services must "include relief of pain and infections, restoration of teeth, and maintenance of dental health." *Id*. The federal agency responsible for overseeing the Medicaid program, the Centers for Medicare and Medicaid Services ("CMS"), interprets this requirement to include coverage for "[o]rthodontic treatment when medically necessary to correct handicapping malocclusion." *See* CMS, The State Medicaid Manual, § 5124.B.2.b.

A state plan need not, however, provide unlimited coverage; to the contrary it must set "reasonable standards … for determining eligibility for and the extent of medical assistance under the plan," as well as provide for procedures and methods of utilization control sufficient to "safeguard against unnecessary utilization of … care and services." 42 U.S.C. §§ 1396a(a)(17) & 1396a(a)(30)(A). In other words, states must develop reasonable standards to ensure they pay for medically necessary services and, at the same time, safeguard against the utilization of services that are not medically necessary. A state plan also must provide "an opportunity for a fair hearing before the State agency" to individuals whose claims are denied. *Id.* § 1396a(a)(3).

The MassHealth Dental Program

MassHealth has an EPSDT program for eligible members younger than 21 years old. 130 C.M.R. § 450.140(A)(1). MassHealth "pays for all medically necessary dental services for EPSDT-eligible members in accordance with 130 CMR 450.140 *et seq.*, without regard to service limitations described in 130 CMR 420.000, and with prior authorization." *Id*. § 420.408. Prior authorization—a form of utilization control—is required for certain dental services, including orthodontic services. *See id.* § 420.410(B)(1) (services with the abbreviation "P.A."

require prior authorization); MassHealth *Dental Manual*, Subchapter 6.

A provider submitting a prior authorization request for orthodontic services must include "appropriate and sufficient documentation to justify the medical necessity for the service." 130 C.M.R. § 420.410(C)(1). For comprehensive orthodontic services, the provider must show that the member "has a handicapping malocclusion." *Id.* § 420.431(C)(3). A provider submits this information on the HLD Index Form, found in Appendix D of MassHealth's Dental Manual. *Id*. This sub-regulatory form gives providers three alternative ways to show the member's need for treatment. First, the provider may show that the member has one of seven conditions that automatically qualifies them for treatment. Second, the provider may score the member based on several measurements, with a score of 22 or more qualifying the member for treatment. Finally, the provider may submit a medical necessity narrative, with accompanying documentation, specifically explaining why comprehensive orthodontic treatment is medically necessary to treat the individual member's handicapping malocclusion. If MassHealth's third-party administrator ultimately determines that the provider's showing on all three prongs is inadequate, MassHealth denies the prior authorization and the member has a right to an administrative hearing on appeal.[1]

When notifying a member of an adverse prior authorization determination, MassHealth must inform the member in writing of the right to a fair hearing, how to request the hearing, and of the right to an "appeal representative."[2] 130 C.M.R. §§ 610.031(A), 610.032(A)(1). A fair hearing provides "an administrative determination of the appropriateness of [the prior authorization denial]." 130 C.M.R. § 610.012(A). The request must be received by MassHealth's Board of Hearings within 30 days after the member receives written notice of the denial. *Id.*

[1] MassHealth also gives providers a separate avenue to request reconsideration of the decision. *See* Cmp. Exh. I.

[2] An "appeal representative" is someone who, at the appellant's own expense, may "exercise on the appellant's behalf any of the appellant's rights under 130 CMR 610.000." *Id.* § 610.016(A).

§ 610.015(B). During the hearing, the member (or their appeal representative) may present witnesses, introduce documentary evidence and oral testimony, cross-examine adverse witnesses, and advance pertinent arguments. *Id.* § 610.061(A)-(F). The hearing officer's final decision is subject to judicial review under G.L. c. 30A. 130 C.M.R. § 610.092.

MassHealth's Technical Alterations to the HLD Index Form

In March and June 2020, MassHealth made several updates and clarifications to the two pages of instructions that accompany the HLD Index Form. *See* Cmp., Exh. E, pp. 7-8. MassHealth noted the technical edits and clarifications in transmittal letter 104. Cmp. Exh. D, p. 1. Transmittal letter 106, which attached the operative HLD Index, describes the cumulative updates in detail. Cmp. Exh E, p. 1. The plaintiffs complain about three of those changes in their five-count verified complaint. *See* Cmp. ¶¶ 78-95. They are:

> **Labio-Lingual spread**: MassHealth now instructs providers to score labio-lingual spread by measuring the arch with the greatest spacing. It made this technical change to maintain consistency with medical research and the practices of other state Medicaid agencies.[3]
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> **Mandibular Protrusion**: MassHealth changed the instruction for measuring mandibular protrusion so that it is recorded with the patient in the centric occlusion and measured from the labial of the lower permanent incisor to the labial of the upper permanent incisor. The instruction further clarifies that the condition must involve two or more adjacent permanent incisors in reverse overjet, not just a single permanent tooth in crossbite. The instruction is consistent with medical research and at least 14 other states use the incisors instead of a back tooth as the reference point.
>
> **Open Bite**: MassHealth clarified the instruction for measuring open bite (*i.e.*, the absence of vertical overlap of a maxillary and mandibular permanent incisor) to have consistency between the HLD Index Form (which required measurement from the incisors) and the instruction, which lacked that specificity. The instruction now tells providers not to count permanent canines or end to end or edge to edge permanent incisors when measuring open bite. Rather, to be counted the entire maxillary incisal edge must not have any end to end contact with a mandibular incisor or any vertical overlap of the mandibular incisor. It is measured from the incisal edge of the permanent maxillary incisor to the incisal edge of the permanent mandibular incisor.

[3] The HLD Index was developed by and largely follows the instructions of Harry Draker. *See* Harry L. Draker, *Handicapping Labio-Lingual Deviations: A Proposed Index For Public Health Purposes*, American Journal of Orthodontics, Vol. 46, No. 4, pp. 295-305 (April 1960).

ARGUMENT

I. The Plaintiffs Lack Standing.

The children and the organizational plaintiff, Medicaid Orthodontists of Massachusetts, Association, Inc., ("MOMA") lack standing. This Court should therefore dismiss the complaint for lack of subject matter jurisdiction. *HSBC Bank U.S.A., N.A. v. Matt*, 464 Mass. 193, 199 (2013) ("Courts … have both the power and obligation to resolve questions of subject matter jurisdiction whenever they become apparent"); *see also Steel Co. v. Citizens for a Better Env't*, 523 U.S. 83, 94 (1998) ("Without jurisdiction the court cannot proceed at all in any cause. Jurisdiction is power to declare the law, and when it ceases to exist, the only function remaining to the court is that of announcing the fact and dismissing the cause.").

The Child Plaintiffs. The five named child plaintiffs lack standing for three reasons. Each one is independent grounds to dismiss them from the case.

First, the children's allegations about their injury, the cause of their injury, and the linkage between the two are deficient. *See Ginther v. Comm'r of Ins.*, 427 Mass. 319, 323 (1998), quoting *Northbridge v. Natick*, 394 Mass. 70, 75 (1985) ("Alleging '[i]njury alone is not enough; a plaintiff must allege a breach of duty owed to it by the public defendant.' "). Whatever orthodontic complications the children may have, the complaint does not allege that they have handicapping malocclusions that make comprehensive orthodontic treatment medically necessary under MassHealth regulations.[4] It also offers no factual allegations or supporting exhibits (*i.e.*, the prior authorization forms, with supporting documentation, submitted on the children's behalf) to support the conclusory statements in paragraphs 96-128 that the prior authorization requests would have been approved but for MassHealth's changes to the HLD Index Form's instructions. *Slama v. Attorney Gen.*, 384 Mass. 620, 624 (1981) ("To have

[4] Paragraph 120 does allege that Ana has a handicapping malocclusion, but it does not allege that comprehensive orthodontic treatment is medically necessary.

standing in any capacity, a litigant must show that the challenged action has caused the litigant injury”). Finally, it fails to connect the prior authorization request denials to the three instructional changes the plaintiffs challenge.[5] *Id*. Without these critical facts, this Court should give no weight, for purposes of standing, to the plaintiffs’ conclusory allegations that they have been injured by MassHealth’s clarifications to the HLD’s instructions. *See Pishev v. City of Somerville*, 95 Mass. App. Ct. 678, 682 (2019) (“A factual challenge to subject matter jurisdiction gives no presumptive weight to the averments in the plaintiffs’ complaint, and requires the court to address the merits of the jurisdictional claim by resolving the factual disputes between the plaintiffs and the defendants.”) (internal quotations omitted).

Second, even if the plaintiffs had alleged that the children have a handicapping malocclusion for which comprehensive orthodontic treatment is medically necessary *and* attributed their individual harm to a specific change in the HLD Index Form, the complaint fails to allege that the children’s orthodontists completed all three aspects of the form. This missing allegation is crucial here, because establishing an automatically qualifying condition, or a score of 22 or greater, are not the only ways for a provider to demonstrate medical necessity for orthodontic treatment. Indeed, the form offers providers a third method to establish a patient’s medical need due to a handicapping malocclusion, called the medical necessity narrative, to be used in cases where qualification is not established under the form’s first two prongs. Moreover, the instructions for the narrative expressly state that it should be used in cases like the plaintiffs, where the member has an inability to eat or chew that the provider believes amounts to a

[5] In paragraphs 78-94, plaintiffs focus on changes to three aspects of the HLD—the instructions for determining labio-lingual spread, *see* Cmp., ¶ 78, the instructions for determining mandibular protrusion, *see id.*, ¶¶ 80, 82-27, and the definition of anterior open bite, *see id*. ¶¶ 90-95. But nowhere in the complaint do they link these conditions to the children. And although plaintiffs offer further details on the children’s alleged conditions on page 8 of their memorandum, they offer no citation for the conditions, a critical omission where these details are not mentioned in the verified complaint or Dr. Rizkallah’s supporting affidavit.

handicapping malocclusion. *See* Cmp. Exh. E, p. 5. *See also id*. ¶¶ 97, 104, 109, 114, 120 (detailing each child's difficulty chewing). Thus, any alleged shortcoming in the form's instructions cannot cause a patient injury unless the complaint also alleges that a handicapping malocclusion has been established using the narrative but was erroneously denied nonetheless by MassHealth. Since the complaint does not include such allegations and plaintiffs failed to attach their prior authorization requests to the complaint,[6] plaintiffs cannot establish any harm.[7]

Finally, even if the child plaintiffs satisfied those standing prerequisites, they have an additional problem—they failed to exhaust administrative remedies after their prior authorization request denials. *See Wilczweski v. Comm'r of Dep't of Envt'l Quality Eng'g*, 404 Mass. 787, 782 (1989) ("administrative remedies should be exhausted before resort to the courts."); *see also Villages Dev. Co. v. Sec'y of Exec. Office of Envtl. Affairs*, 410 Mass. 100, 106 (1991) ("To secure declaratory relief in a case involving administrative action, a plaintiff must show that (1) there is an actual controversy; (2) he has standing; (3) necessary parties have been joined; and (4) available administrative remedies have been exhausted."). Under MassHealth regulations, a member (or their appeal representative) may request a fair hearing to challenge "the appropriateness of [the prior authorization denial]." 130 C.M.R. § 610.012(A)(1). During that hearing, the member (or their appeal representative) may present witnesses, introduce

[6] Because this Court may consider "affidavits and other matters outside the face of the complaint relevant to the issue of subject matter jurisdiction," *see Ginther*, 427 Mass. at 323 n.6, to supplement this argument, the defendants intend to seek permission during tomorrow's motion hearing to file under seal an authenticating affidavit with the child plaintiffs' redacted prior authorization requests and the redacted prior authorization denials.

[7] The specific orthodontic conditions scored require making certain measurements and placing them on the form. The complaint, however, offers no measurements, instead describing how each child plaintiff is impacted by their condition, e.g., Dayanne N. "has difficulty chewing . . . has to pull [her food] forward out of her mouth with her hands . . . [which] has damaged her lower front teeth." Cmp. ¶¶ 97, 98. The medical necessity narrative gives the provider the opportunity to specifically describe the patient's condition, including "a substantiated inability to eat or chew caused by the patient's malocclusion," but the complaint fails to allege that any information was given to MassHealth to help show medical necessity. Cmp., Exh. E.

documentary evidence and oral testimony, cross-examine adverse witnesses, and argue why treatment is medically necessary. *Id.* § 610.061(A)-(F). The hearing officer's final decision is subject to judicial review under G.L. c. 30A. 130 C.M.R. § 610.092. Because the complaint does not allege that the child plaintiffs (or their appeal representatives) sought administrative review of their prior authorization denials, they failed to exhaust administrative remedies, depriving MassHealth of "a full and fair opportunity to apply its expertise" to the circumstances of the child-plaintiffs' claims that they should have been approved for treatment. *See Mass. Resp. Hosp. v. Dep't of Pub. Welf.*, 414 Mass. 330, 336-337 (1993) (hospital precluded from seeking judicial review of Medicaid claims denial where hospitals failed to pursue administrative remedies); *Gill v. Bd. of Reg. of Psych.*, 399 Mass. 724, 727 (1987). *See also Athol Mem. Hosp. v. Comm'r of Div. of Med. Assist.*, 437 Mass. 417, 421-422 (2002) (hospitals required to pursue administrative appeals of and properly denied judicial review where they failed to do so).

MOMA. MOMA also lacks standing. *See Statewide Towing Ass'n v. City of Lowell,* 68 Mass App. Ct. 791, 794 (2007). When an association like MOMA "asserts associational standing on behalf of its members, it must establish that its members would independently have standing to pursue the claim." *Id.,* citing *Animal Legal Def. Fund, Inc., v. Fisheries & Wildlife Bd.*, 416 Mass. 635, 638 n.4 (1993). But here, the sole paragraph in the verified complaint about MOMA, *see* Cmp. ¶ 7, fails to meet that jurisdictional obligation. All it alleges is that "MOMA's members include [1] families and children who are Medicaid beneficiaries who need or may need orthodontic services and [2] orthodontists who participate as providers in the MassHealth Medicaid program who are personally aggrieved by the denial of necessary orthodontic services to their Medicaid patients." *Id.* It does not establish that any of MOMA's unidentified child members had a prior authorization request filed on their behalf, that the prior authorization request was denied, that the denial was a direct result of MassHealth's changes to the HLD, and that the member exhausted their available administrative remedy. *See Statewide*, 68 Mass. App. Ct. at 795 ("[s]peculative injuries insufficient to confer standing"). Similarly, while paragraph 7 does contain a conclusory allegation that some MOMA-member orthodontists are "aggrieved," that they "will not be paid for services that [they] ha[ve] not been authorized to perform does not make [them] aggrieved part[ies]."[8] *Rizkallah v. Dir. of the Mass. Office of Medicaid*, 85 Mass. App. Ct. 1104, *1 (2014) (Rule 1:28 decision). *See Ginther*, 427 Mass. at 322 ("[O]nly persons who have themselves suffered, or who are in danger of suffering, legal harm can compel the courts to assume the difficult … duty of passing upon the validity of acts of a coordinate branch of government") (internal citations omitted). Plaintiffs cite no law supporting the notion that a provider suffers an injury when a patient's claim is denied. Nor can they—only MassHealth members have claims for coverage of medical conditions.

II. Plaintiffs Do Not Have a Likelihood of Success on Their Claims.

Plaintiffs do not have a likelihood of success on the merits of their claims because each count of the complaint should be dismissed for failure to state a claim.

A. MassHealth's Administrative Changes to the HLD Index Form's Instructions Do Not Interfere with the Plaintiffs' EPSDT Rights.

In Count I, plaintiffs claim that the administrative changes to the HLD Index Form's instructions interfere with several EPSDT provisions. Their claim should be dismissed.

1. Where the Medical Necessity Narrative is Available For Use By Providers to Show the Member's Handicapping Malocclusion, Plaintiffs Cannot Establish that MassHealth's Administrative Changes to Other Portions of the HLD Index Form's Instructions Interfere with the Plaintiffs' EPSDT Rights.

The EPSDT claim under 42 U.S.C. §§ 1396a(a)(10)(A) and 1396d(a)(4)(B), which require MassHealth to provide EPSDT services to members, fails. This is because the success of the claim hinges on the erroneous assertion that the existence of a handicapping malocclusion

[8] Compounding the standing problem, paragraph 7 contains no factual support establishing that any MOMA orthodontist filed prior authorization requests on behalf of patients, that the requests were denied, that the denial was a direct result of MassHealth's HLD changes, and that the member exhausted available administrative remedies. *Statewide*, 68 Mass. App. Ct. at 794-95.

rises or falls solely by reference to the first two portions of the HLD Index Form (which they claim has been wrongly altered). This is not the case. Where medical necessity can be established using the medical necessity narrative and where there are no allegations that it has been used for plaintiffs, there simply cannot be a showing that the EPSDT standards have been violated. That the narrative's instructions specify that it should be used when there is a "substantiated inability to eat or chew caused by the patient's malocclusion," Cmp. Exh. E. p. 5, something the complaint alleges the child plaintiffs suffer from, compounds plaintiffs' problem.

Plaintiffs are also incorrect in suggesting that the changes to the language of certain definitions germane to the use of the HLD Index Form somehow violate the rules regarding the medically necessary nature of the services provided. For example, plaintiffs claim that the definitional changes violate 130 C.M.R. § 450.204 because the regulation requires that "medically necessary services must be of a quality that meets professionally recognized standards of healthcare," and they assert that the definitional changes are not standard in the industry. But the regulation they cite concerns medical services rendered by a provider. *See* 130 C.M.R. § 450.101 ("provider:" individual that "furnishes medical services and participates in MassHealth under a provider contract").[9] It says nothing about the methods MassHealth uses to assess whether there is a medical necessity for a provider to treat a patient. Moreover, the complaint does nothing more than assert, as a factual matter, that the definitions used in the HLD Index instructions, for example, depart from "well-established industry diagnostic definitions." Cmp. ¶ 80. This repeated assertion, without further explication, is inadequate to state a claim.[10]

[9] So, for example, an orthodontist authorized to treat a member's handicapping malocclusion would violate this regulation if they used a sledgehammer to adjust the patient's teeth, and MassHealth would not be legally bound to pay, because such "treatment" does not "meet[] professionally recognized standards of healthcare," under 130 CMR § 450.204.

[10] It is also factually wrong: the HLD Indexes of California, Illinois, New Jersey, and New York use definitions and instructions similar to the Massachusetts HLD Index. Some of these states are stricter, not allowing for the scoring of spacing of the arches at all in calculating labio-lingual

2. Plaintiffs Have Not Established that MassHealth Failed to Arrange for Comprehensive Orthodontic Treatment.

Plaintiffs' EPSDT claim under 42 U.S.C. § 1396a(a)(43) also fails. That section requires MassHealth to (a) inform all eligible persons in the state under age 21 of the availability of EPSDT services, (b) provide or arrange for screening in all cases where they are requested, (c) arrange for corrective treatment if it is disclosed by the screening, and (d) report EPSDT utilization data to CMS. 42 U.S.C. §§ 1396a(a)(43)(A)-(D).

Although the complaint does not specify which subpart of Section 1396a(a)(43) the claim arises from, plaintiffs appear to confuse the requirements for EPSDT screening and treatment. They cite to the requirements of 42 C.F.R. § 441.56(b)(2) that EPSDT screening services must be "in accordance with reasonable standards of medical and dental practice determined by the agency ***after consultation with recognized medical and dental organizations8*** involved in child health care." PI Mem p. 6 (emphasis added by plaintiffs). But these requirements relate to screening services as set forth in a state agency's periodicity schedule, as opposed to the dispute over when treatment is required at issue in the current litigation.[11]

In fact, the only plausible claim arises under sub-section (C), which concerns the post-screening arrangement for corrective treatment.[12] But here, after plaintiffs were screened and

spread. *See* https://www.denti-cal.ca.gov/DC_documents/providers/DC016.pdf; https://www.illinois.gov/hfs/SiteCollectionDocuments/2017DORM.pdf; https://www.njmmis.com/downloadDocuments/29-16.pdf; https://www.emedny.org/ProviderManuals/Dental/PDFS/HLD_Index_NY.pdf.

[11] *See* https://www.medicaid.gov/medicaid/benefits/early-and-periodic-screening-diagnostic-and-treatment/index.html ("At a minimum, dental services include relief of pain and infections, restoration of teeth, and maintenance of dental health. Dental services may not be limited to emergency services. Each state is required to develop a dental periodicity schedule in consultation with recognized dental organizations involved in child health.")

[12] Since the complaint alleges that all the named plaintiffs had prior authorization requests submitted on their behalf, they lack standing to challenge MassHealth's compliance with the obligations to inform members about, and then arrange for, screening services. 42 U.S.C.

their orthodontists submitted prior authorization requests, MassHealth's third-party administrator determined that the partially completed prior authorization requests did not establish that any plaintiff had a handicapping malocclusion or that treatment was medically necessary. No plaintiff pursued a fair hearing to challenge the prior authorization denials. And given the lack of administrative challenge to the determination that comprehensive orthodontic treatment was not medically necessary, MassHealth had nothing to "arrange" under Section 1396a(a)(43)(C).

3. Plaintiffs Have Failed to Establish that MassHealth Violated 42 U.S.C. § 1396d(r)(3).

Plaintiffs also cite 42 U.S.C. § 1396d(r)(3)(B), which requires that dental services "shall at a minimum include relief of pain and infections, restoration of teeth, and maintenance of dental health." If this is an independent aspect of the EPSDT claim, it is undeveloped in both the complaint and the preliminary injunction memorandum, and for that reason alone, this Court should dismiss it. Further, the claim fails because the Medicaid Act requires MassHealth to use "reasonable standards … for determining eligibility" as well as implement methods of utilization control sufficient to "safeguard against unnecessary utilization of … care and services," *see* 42 U.S.C. §§ 1396a(a)(17) & 1396a(a)(30)(A), which is exactly what MassHealth did here. If the child plaintiffs were aggrieved by MassHealth's denial of their prior authorization requests, they should have submitted medical necessity narratives or requested fair hearings to explain how their pain and dental health problems amounted to handicapping malocclusions that make comprehensive orthodontic treatment medically necessary under MassHealth regulations.

B. MassHealth Was Not Required to Make Technical Alterations to the Directions for Using a Sub-Regulatory Form by Way of Regulation.

The HLD Index Form is a sub-regulatory document maintained by MassHealth to aid orthodontists submitting prior authorization requests. In Count II, plaintiffs claim that technical

§ 1396a(a)(43)(A)-(B). Likewise, they lack both standing and a cause of action to challenge the adequacy of MassHealth's reports to CMS. *Id*. § 1396a(a)(43)(D).

alterations MassHealth made to the form's instructions in March and June should have been done via regulation. *See* Cmp. ¶¶ 138-146; PI Mem. pp. 9-12. Their argument fails for two reasons.

First, the standard for comprehensive orthodontic treatment is unchanged. Just like before the complained-of alternations, the provider must demonstrate the patient has a handicapping malocclusion for which comprehensive treatment is medically necessary. Providers continue to have three ways to demonstrate this on the HLD Index Form. First, they can demonstrate that a patient has an automatically qualifying condition. Second, they may show that the patient scored 22 or higher on the HLD's scoring index. Third, the provider can present a medical necessity narrative detailing why the patient has a handicapping malocclusion. Here, MassHealth made minor adjustments to the form's first two aspects that function as shortcuts for showing medical necessity. That MassHealth clarified measuring instructions for those shortcuts because they were causing provider confusion and the lack of precise definitions was resulting in overutilization does not amount to a change that must follow the c. 30A. This is because the changes do not, as a matter of law, result in a material change in the policy that excludes medically necessary cases, as the third method (the catch-all) remains unchanged, with the provider retaining the ability to describe in a narrative why treatment is medically necessary.[13]

Second, the instructional clarifications and updates themselves, which, again, were intended to fill in details and clarify ambiguities that were resulting in provider confusion and overutilization, are themselves not the type of alterations that trigger the c. 30A process. *See Genworth Life Ins. Co. v. Comm'r of Ins.*, 95 Mass. App. Ct. 392, 396 (2019), quoting *Mass. Gen. Hosp. v. Rate Setting Comm'n*, 371 Mass. 705, 707 (1977) ("administrative agency may use

[13] That the narrative is not used as frequently as the other two methods does not mean that it is not a viable means of establishing medical necessity. Consistent with its regulations and federal law, MassHealth could require that every provider show medical necessity in narrative form. The two shortcuts to the narrative (autoqualifying conditions and scoring) ease administration of the prior authorization process, and MassHealth can of course determine that closer cases require a more precise evidentiary showing, whether in the form of measurements, narrative, or both.

sub-regulatory guidance to 'fill in the details or clear up an ambiguity of an established policy' without resort to formal rulemaking as long as it does not contradict its enabling statute or preexisting regulations"). They were instead designed to improve the accuracy and consistency of the medical necessity determinations.[14]

The instructions at issue here do not conflict with the applicable regulations, but rather align with the requirements in 130 C.M.R. § 420.431(C)(3) that the MassHealth agency describe the standards for medical necessity in sub-regulatory guidance. The case for the use of sub-regulatory guidance is especially compelling when it is called for by the regulation itself. The instructions provide a method to administer the prior authorization process in a manner that identifies medically necessary cases while still following the federal government's instruction that MassHealth not pay for treatment that is not medically necessary. *See Genworth Life Ins. Co.*, 95 Mass App. Ct. at 396. *See also Arthurs v. Bd. of Reg. in Med.*, 383 Mass. 299, 313 n.26 (1981) (agency filling in details or clarifying ambiguity may issue interpretation or informational pronouncements without going through the procedures required for promulgating regulations). In furtherance of that, the challenged instructions merely (1) clarify ambiguities in how providers should perform measurements required by the form for "open bite" and (2) offer greater detail on when labio-lingual spread and mandibular protrusion automatically amounts to a handicapping malocclusion for which comprehensive treatment is medically necessary, providing details and clarifying ambiguity on when a member has a handicapping malocclusion requiring treatment. These changes do not restrict eligibility or access to services. Rather, the test for coverage remains whether the patient has a handicapping malocclusion for which orthodontic treatment is medically necessary based on clinical standards described in Appendix D.[15]

[14] *See, e.g.,* Cmp. Exh. F, p.2 (cited emails where the third-party administrator's vice president of clinical management notes the updates will make reviews "more accurate and consistent").

[15] In estimating that the clarification will result in 60% of previously approved cases being denied, Dr. Rizkallah offers no indication about how that would change if he utilized the medical

C. MassHealth is Not Discriminating Against Members in the Provision of Services.

Count III—a claim under G.L. c. 151B, § 4(10)—fails to state a viable claim, for four independent reasons. First, to state a claim under section 4(10), plaintiffs must establish that the state defendants are the "person[s] furnishing … services[.]" The defendants, however, do not "furnish" any services. Rather, MassHealth members seek out MassHealth providers to furnish the services and then the provider submits a bill to MassHealth for payment.

Second, plaintiffs are wrong that MassHealth's changes to the instructions for the HLD Index Form equate to a change to the service (comprehensive orthodontic treatment) itself. There are no allegations in the complaint that the service that providers perform on children who receive prior authorization for comprehensive orthodontic treatment is any different now than it was before March 2020. Nor could there be, as the allegations in the complaint only concern providers having to take different measurements than they would allegedly prefer to obtain prior authorization for the service they hope to provide. Further, the regulatory definition of "comprehensive orthodontic treatment" in 130 C.M.R. § 420.431(B)(3) is unchanged and MassHealth continues to pay for comprehensive orthodontic treatment to those children for whom it is medically necessary and have obtained prior authorization.

Third, even if plaintiffs could ultimately prove their allegations, they still need to establish that the defendants are discriminating against MassHealth members because they are MassHealth members. But a state agency adjusting its methodology for the administration of the prior authorization approval process for a service available to members is not, as a matter of law, discrimination against MassHealth members based on their status as MassHealth members.[16]

necessity narrative, which he stated he uses in only 1% of the cases. Rizkallah Aff. ¶¶ 1, 24. There is thus not factual basis for plaintiffs' claim that the change substantially affects them.

[16] Rather, the complaint describes behavior by MassHealth orthodontic providers that amounts to discrimination by the providers, in violation of G.L. 151B, § 4(10), against MassHealth members *because* they are recipients of Medicaid benefits. That is, the providers are described as refusing

Finally, the allegations in paragraph 151, that MassHealth is "attempting to coerce providers to deny a proper diagnosis and deny an accurate medical record to MassHealth members, when they provide these services to all patients who are not MassHealth members," is wrong as a matter of fact and law. It is wrong as a matter of fact because an orthodontist can diagnose patients as they always have, explaining in what ways a patient's condition reveals a handicapping malocclusion. All the instructions for the HLD Index does is require providers to measure certain distances between certain teeth, measurements that MassHealth requires to verify that the patient's eligibility for treatment is medically necessary under the first two parts of the HLD Index Form. All a provider must do is certify the accuracy of the measurements and the accuracy of the facts presented to justify a claim of medical necessity. It is also wrong as a matter of law because providers are under no obligation to participate in MassHealth and are free to withdraw from program participation at any time. *See, e.g., Boston Med. Ctr. Corp. v. Sec'y of Exec. Office of Health & Human Servs.*, 463 Mass. 447, 459 (2012); cf 130 C.M.R. § 450.249(D) (describing process when MassHealth receives notification of the provider's intention to close or to withdraw from MassHealth). Moreover, it is certainly the case that MassHealth patients and private pay patients are not similarly situated for these purposes. MassHealth patients are only entitled to have MassHealth pay an orthodontist for treatment that is medically necessary, that is, to alleviate a handicapping malocclusion. Other, non-MassHealth, patients are free to have an orthodontist provide services for medically necessary, or solely cosmetic, purposes.

D. There is Not a Medicaid Due Process Right to Peer-to-Peer Review.

Count IV is a due process claim under 42 U.S.C. § 1983, alleging that the defendants have failed to provide adequate due process under the Act, 42 U.S.C. § 1396a(a)(3). Section 1396a(a)(3) requires MassHealth to "provide for granting an opportunity for a fair hearing before the State agency to any individual whose claim for medical assistance under the plan is denied or

to assess and treat MassHealth members for handicapping malocclusions *because* the providers disagree with the measurements MassHealth requires them to record on the HLD Index Form.

is not acted upon with reasonable promptness[.]" Because MassHealth provides the opportunity for a fair hearing to any member whose prior authorization request for comprehensive orthodontic treatment is denied, *see* 130 C.M.R. §§ 610.001(a) & 610.012, the plaintiffs' claim fails as a matter of law and should be dismissed for failure to state a claim.

Plaintiffs do not even acknowledge the fair hearing process in their complaint. Instead, they attempt to portray the informal peer-to-peer telephonic review process that MassHealth's third-party administrator offers orthodontists as a critical avenue for error-correction. But while the peer-to-peer process certainly helps orthodontists augment inadequacies in their prior authorization requests, it is not required by either federal or state law and neither providers nor members have a due process right to it. *Bd. of Regents of State Colleges v. Roth*, 408 U.S. 564, 577 (1972) (to have a protected property interest in a benefit, a person "must have more than an abstract need or desire for it. … He must, instead, have a legitimate claim of entitlement to it."). Indeed peer-to-peer review is mentioned nowhere in Massachusetts statute or regulation. Moreover, even the changes of which plaintiffs complain preserve the opportunity on the part of providers to respond to and augment the information they provide to request a prior authorization. Instead of the peer-to-peer process, providers have the opportunity to submit a reconsideration through the MassHealth provider web portal. *See* Cmp. Exh. I. And, contrary to plaintiffs' claims, limiting the mode of such requests for reconsideration does not limit benefits.

Since members do not participate in the peer-to-peer review process, they certainly have no entitlement to it. Some providers, by contrast, do participate in this process. But that they have no right or entitlement to peer-to-peer telephonic review is consistent with the procedural due process rules surrounding prior authorization denials. Nothing in federal or Massachusetts law confers on providers a protected property interest implicated by the denial of a member's prior authorization request. Additionally, a provider's desire to give an individual comprehensive orthodontic care in the future and be reimbursed is not a protected property interest. The only property interest affected by such denials is the entitlement of MassHealth *members* to receive Medicaid benefits. This is why under federal law, only Medicaid beneficiaries or members—*not providers*—are entitled to a fair hearing challenging the denial of a prior authorization request. *See* 42 U.S.C. § 1396a(a)(3) (providing right to fair hearing to individual whose claim for medical assistance is denied); 42 C.F.R. §§ 431.200-250 (federal regulations governing fair hearings for applicants and beneficiaries). Similarly, under Massachusetts law, a provider has no independent right to request a fair hearing to challenge the denial of a prior authorization request. *See* G.L. c. 118E, § 47; 130 C.M.R. § 610.035(A)(7); *see also Rizkallah v. Dir. of the Mass. Office of Medicaid*, 85 Mass. App. Ct. 1104, *1 (2014) (Rule 1:28 decision), citing *Centennial Healthcare Inv. Corp. v. Comm'r of Div. of Med. Assist.*, 61 Mass. App. Ct. 320, 326-27 (2004) (dental provider has no independent basis to challenge denial of prior authorization request).

III. The Plaintiffs Have Not Demonstrated that They Will Suffer Irreparable Harm.

Because plaintiffs have failed to establish a likelihood of success on any of their claims, this Court need not proceed further. *See, e.g., Student No. 9 v. Board of Educ.*, 440 Mass. 752, 767 (2004). But even if this Court considers their allegations of harm, they fare no better, as they have not demonstrated a risk of irreparable harm in the absence of injunctive relief.

The child plaintiffs have failed to establish that they have been irreparably harmed by MassHealth. It was their orthodontists (not MassHealth) who decided not to complete the medical necessity narratives—narratives that could have explained why the child plaintiffs' chewing problems require comprehensive orthodontic treatment even though they did not qualify under the HLD's first two prongs. Likewise, it was the children and their families (not MassHealth) who decided not to exhaust their administrative remedies through the fair hearing process, a process designed to fix erroneous prior authorization denials and that might have resulted in the children obtaining approval for treatment. Where there is no allegation or evidence that any plaintiff has been, or will be, denied coverage on the ground of a lack of medical necessity, or that the medical necessity narrative has been completed for such patient, the child plaintiffs cannot demonstrate that they have been irreparably harmed by MassHealth.

The "alleged" harms to MOMA's provider-members also do not compel a preliminary injunction, for three reasons. First, as the complaint's allegations make clear, they have known about these changes since March 2020 and have had ample time to file this lawsuit. Second, "[e]conomic harm alone … [does] not suffice as irreparable harm unless the loss threatens the very existence of the movant's business," *see Tri-Nel Mgmt., Inc. v. Bd. of Health of Barnstable*, 443 Mass. 217, 227-228 (2001) (internal citation & quotation omitted), and there are no allegations of that here. Finally, the mere (alleged) adjustment in the eligibility rate of potential patients cannot establish irreparable harm on the part of the providers, particularly where there has been no showing that providers have used the alternative medical necessity narrative.

IV. The Balance of the Harms and the Public Interest Strongly Favor Protecting the Integrity of MassHealth's Administration of Its Orthodontic Program.

Finally, the alleged harms to plaintiffs do not outweigh the harms to MassHealth or justify the interference with the internal administration of its orthodontic program. *See Loyal Order of Moose, Inc., Yarmouth Lodge #2270 v. Bd. of Health of Yarmouth*, 439 Mass. 439 Mass. 597, 601 (2003). MassHealth must provide only services that are medically necessary. Clarifying the HLD's instructions to reduce waste and enhance program integrity in accordance with 42 U.S.C. § 1396a(a)30(A), 64 and 68, ensures that MassHealth's funds are utilized as efficiently as possible. And there is no basis for granting preliminary relief to plaintiffs who neither completed the medical necessity narrative nor exhausted administrative remedies.

CONCLUSION

For the foregoing reasons, the state defendants respectfully request that this Court deny plaintiffs' motion for preliminary injunction and allow the state defendants' motion to dismiss.

Respectfully submitted,

MAURA HEALEY
ATTORNEY GENERAL

/s/ Douglas S. Martland
Douglas S. Martland (BBO # 662248)
David R. Marks (BBO # 548982)
Assistant Attorneys General
One Ashburton Place, Boston, MA 02108
(617) 963-2062/2362
douglas.martland@state.ma.us
david.marks@state.ma.us

August 24, 2020

CERTIFICATE OF SERVICE

I certify that on this date I served by email a copy of the forgoing Memorandum in Opposition to Plaintiffs Motion for Preliminary Injunction and in Support of Defendants' Motion to Dismiss on counsel for the plaintiffs—Joel Rosen and Matthew Perry.

/s/ Douglas S. Martland
Douglas S. Martland
Assistant Attorney General

August 24, 2020

Handicapping Labio-Lingual Deviation Index Scoring Instructions

All measurements are made with a measurement tool scaled in millimeters. Absence of any conditions must be recorded by entering "0" (See attached form).

The following information should help clarify the categories on the HLD Index.

1. **Cleft Palate Deformities:** Indicate an "X" on the form. (*This is considered an autoqualifying condition*.)
2. **Deep Impinging Overbite:** Indicate an "X" on the form when lower incisors are destroying the soft tissue of the palate (e.g., ulcerations or tissue tears – more than indentations). *(This is considered an autoqualifying condition.)*
3. **Anterior Impactions:** Indicate an "X" on the form. Anterior impactions include central incisors, lateral incisors, and canines in the maxillary and mandibular arches. *(This is considered an autoqualifying condition.)*
4. **Severe Traumatic Deviations:** Indicate an "X" on the form. Traumatic deviations refers to facial accidents rather than congenital deformity. For example, loss of a premaxilla segment by burns or by accident; the result of osteomyelitis; or other gross pathology. Do not include traumatic occlusions or crossbites. *(This is considered an autoqualifying condition.)*
5. **Overjet greater than 9mm:** Indicate an "X" on the form. This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. The measurement could apply to a protruding single tooth as well as to the whole arch. The measurement is read and rounded off to the nearest millimeter and entered on the form. *(This is considered an autoqualifying condition.)*
6. **Reverse overjet greater than 3.5mm:** Indicate an "X" on the form. This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. *(This is considered an autoqualifying condition.)*
7. **Severe Maxillary Anterior Crowding, greater than 8mm**: Indicate an "X" on the form. *(This is considered an autoqualifying condition.)*
8. **Overjet in Millimeters:** This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. The measurement could apply to a protruding single tooth as well as to the whole arch. The measurement is read and rounded off to the nearest millimeter and entered on the form.
9. **Overbite in Millimeters:** A pencil mark on the tooth indicating the extent of overlap facilitates this measurement. It is measured by rounding off to the nearest millimeter and entered on the form. Reverse" overbite may exist in certain conditions and should be measured and recorded.
10. **Mandibular Protrusion in Millimeters:** Score exactly as measured from the buccal groove of the first mandibular molar to the MB cusp of the first maxillary molar. The measurement in millimeters is entered on the form and multiplied by 5.
11. **Open Bite in Millimeters:** This condition is defined as the absence of occlusal contact in the anterior region. It is measured from edge to edge in millimeters. This measurement is entered on the form and multiplied by 4. In cases of pronounced protrusion associated with open bite, measurement of the open bite is not always possible. In those cases, a close approximation can usually be estimated.
12. **Ectopic Eruption:** Count each tooth, excluding third molars. Enter the number of teeth on the form and multiply by 3. If Condition No. 13, Anterior Crowding, is also present, with an ectopic eruption in the anterior portion of the mouth, score only the most severe condition. Do not score both conditions.
13. **Anterior Crowding:** Arch length insufficiency must exceed 3.5 mm. Mild rotations that may react favorably to stripping or mild expansion procedures are not to be scored as crowded. Enter 5 points for maxillary and mandibular anterior crowding. If Condition No. 12, ectopic eruption, is also present in the anterior portion of the mouth, score the most severe condition. Do not score both conditions.

14. **Labio-Lingual Spread:** The measurement tool is used to determine the extent of deviation from a normal arch. Where there is only a protruded or lingually displaced anterior tooth, the measurement should be made from the incisal edge of that tooth to the normal arch line. Otherwise, the total distance between the most protruded tooth and the lingually displaced anterior tooth is measured. The labio-lingual spread probably comes close to a measurement of overall deviation from what would have been a normal arch. In the event that multiple anterior crowding of teeth is observed, all deviations from the normal arch should be measured for labio-lingual spread, but only the most severe individual measurement should be entered on the index.

    A. Additionally, anterior spacing may be measured as the total score in mm from the mesial of cuspid to the mesial of cuspid, totaling both arches.

    Only score the greater score attained by either of these two methods.

15. **Posterior Unilateral Crossbite:** This condition involves two or more adjacent teeth, one of which must be a molar. The crossbite must be one in which the maxillary posterior teeth involved may either be both palatal or both completely buccal in relation to the mandibular posterior teeth. The presence of posterior unilateral crossbite is indicated by a score of 4 on the form.

16. **Posterior impactions or congenitally missing posterior teeth**: Total the number of posterior teeth, excluding third molars that meet this criterion and multiply by 3.

ILLEGAL DEFINITIONS - ENJOINED FROM USE 12-14-2020

Handicapping Labio-Lingual Deviation Index Scoring Instructions

1. Occlude patient or models in centric occlusion.
2. Record all measurements in the order given and rounded off to the nearest millimeter.
3. Enter score "0" if condition is absent.
4. Start by measuring overjet of the most protruding incisor.
5. Measure overbite from the labio-incisal edge of overlapped front tooth (or teeth) to point of maximum coverage.
6. Score all other conditions listed.
7. **Ectopic eruption and anterior crowding: Do not double score**. Record the more serious condition.
8. Deciduous teeth and teeth not fully erupted should not be scored.

All measurements are made with a measurement tool scaled in millimeters. Absence of any conditions must be recorded by entering "0."

The following information should help clarify the categories on the HLD Index.

1. **Cleft Palate Deformities:** Indicate an "X" on the form. (*This is considered an autoqualifying condition*.)

2. **Deep Impinging Overbite:** Indicate an 'X" on the form when lower incisors are destroying the soft tissue of the palate (e.g., ulcerations or tissue tears – more than indentations). *(This is considered an autoqualifying condition.)*

3. **Anterior Impactions:** Indicate an "X" on the form. Anterior impactions include central incisors, lateral incisors, and canines in the maxillary and mandibular arches. *(This is considered an autoqualifying condition.)*

4. **Severe Traumatic Deviations:** Indicate an "X" on the form. "Traumatic deviations" refers to facial accidents rather than congenital deformity (e.g., loss of a premaxilla segment by burns or by accident; the result of osteomyelitis; or other gross pathology). Do not include traumatic occlusions or crossbites. *(This is considered an autoqualifying condition.)*

5. **Overjet Greater Than 9 mm:** Indicate an "X" on the form. This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. The measurement could apply to a protruding single tooth as well as to the whole arch. The measurement is read and rounded off to the nearest millimeter and entered on the form. *(This is considered an autoqualifying condition.)*

6. **Reverse Overjet Greater Than 3.5 mm:** Indicate an 'X" on the form. This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. The measurement is taken horizontally from the labial of the incisal edge of the mandibular incisor to the nearest point of the labial of the surface of the maxillary incisor. A single tooth in crossbite should not be considered as mandibular protrusion. Reverse overjet greater than 3.5 mm may be demonstrated with a measuring device to verify the claimed measurement. The provider may submit a photo with the measuring device (Boley gauge, disposable ruler, or probe) in the patient's mouth, or on models mounted in centric occlusion. (*This is considered an autoqualifying condition.)*

7. **Overjet in Millimeters:** This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. The measurement could apply to a protruding single tooth as well as to the whole arch. The measurement is read and rounded off to the nearest millimeter and entered on the form.

8. **Overbite in Millimeters:** A pencil mark on the tooth indicating the extent of overlap facilitates this measurement. It is measured by rounding off to the nearest millimeter and entered on the form. 'Reverse" overbite may exist in certain conditions and should be measured and recorded.

9. **Mandibular Protrusion in Millimeters:** This is recorded with the patient in centric occlusion and measured from the labial of the lower permanent incisor to the labial of the upper permanent incisor. This condition must involve two or more adjacent permanent incisors in reverse overjet. A single permanent tooth in crossbite should not be considered as mandibular protrusion. The measurement is taken horizontally from the labial of the incisal edge of the mandibular incisor to the nearest point of the labial of the surface of the maxillary incisor. Mandibular protrusion greater than 3.5 mm should be marked in the autoqualifier section and should be demonstrated with a measuring device to verify the claimed measurement. The provider may submit a photo with the measuring device (Boley Gauge, disposab
mounted in centric occlusion. For a measurement of mandibular protrusion less than 3.5 mm, the measurement in millimeters is entered on the form and multiplied by 5.

10. **Open Bite in Millimeters:** This condition is defined as absence of vertical overlap of a maxillary and mandibular permanent incisor. End to end or edge to edge permanent incisors do not count as an open bite. Permanent canines are not scored. To be counted, the entire maxillary incisal edge must not have any end to end contact with a mandibular incisor or any vertical overlap of the mandibular incisor. It is measured from the incisal edge of the permanent maxillary incisor to the nearest point of the incisal edge of the permanent mandibular incisor. This measurement is entered on the form and multiplied by 4.

11. **Ectopic Eruption:** Count each tooth, excluding third molars. Each qualifying tooth must be 100% blocked out of the arch. Enter the number of teeth on the form and multiply by 3. If Condition No. 12, anterior crowding, is also present, with an ectopic eruption in the anterior portion of the mouth, score only the most severe condition. Do not score both conditions.

12. **Anterior Crowding:** Arch length insufficiency must exceed 3.5 mm. Score only fully erupted incisors and canines. Mild rotations that may react favorably to stripping or mild expansion procedures are not to be scored as crowded. Enter 5 points for maxillary and mandibular anterior crowding. If Condition No. 11, ectopic eruption, is also present in the anterior portion of the mouth, score only the most severe condition. Do not score both conditions.

13. **Labio-Lingual Spread:** The measurement tool is used to determine the extent of deviation from a normal arch. Where there is only a protruded or lingually displaced anterior tooth, the measurement should be made from the incisal edge of that tooth to the normal arch line. Otherwise, the total distance between the most protruded tooth and the lingually displaced anterior tooth is measured. The labio-lingual spread probably comes close to a measurement of overall deviation from what would have been a normal arch. If multiple anterior crowding of teeth is observed, all deviations from the normal arch should be measured for labio-lingual spread, but only the most severe individual measurement should be entered on the index.

    - Additionally, anterior spacing may be measured as the total score in mm from the mesial of cuspid to the mesial of cuspid. Only score the arch with the greatest spacing.

      Score only the greater score attained by either of these two methods.

14. **Posterior Unilateral Crossbite:** This condition involves two or more adjacent maxillary permanent teeth, one of which must be a permanent molar. The crossbite must be one in which the maxillary posterior teeth involved may either be both palatal or both completely buccal in relation to the mandibular posterior teeth. The presence of posterior unilateral crossbite is indicated by a score of 4 on the form.

15. **Posterior Impactions or Congenitally Missing Posterior Teeth**: Total the number of posterior teeth, excluding third molars, that meet this criterion, and multiply by 3.

2021 REVERTED DEFINITIONS AFTER INJUNCTION

Handicapping Labio-Lingual Deviation Index Scoring Instructions

All measurements are made with a measurement tool scaled in millimeters. Absence of any conditions must be recorded by entering "0."

The following information should help clarify the categories on the HLD Index.

1. **Cleft Palate Deformities:** Indicate an "X" on the form. (*This is considered an autoqualifying condition*.)
2. **Deep Impinging Overbite:** Indicate an "X" on the form when lower incisors are destroying the soft tissue of the palate (e.g., ulcerations or tissue tears–more than indentations). *(This is considered an autoqualifying condition.)*
3. **Anterior Impactions:** Indicate an "X" on the form. Anterior impactions include central incisors, lateral incisors, and canines in the maxillary and mandibular arches. *(This is considered an autoqualifying condition.)*
4. **Severe Traumatic Deviations:** Indicate an "X" on the form. Traumatic deviations refer to facial accidents rather than congenital deformity. For example, loss of a premaxilla segment by burns or by accident; the result of osteomyelitis; or other gross pathology. Do not include traumatic occlusions or crossbites. *(This is considered an autoqualifying condition.)*
5. **Overjet Greater Than 9mm:** Indicate an "X" on the form. This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. The measurement could apply to a protruding single tooth as well as to the whole arch. The measurement is read and rounded off to the nearest millimeter and entered on the form. *(This is considered an autoqualifying condition.)*
6. **Reverse Overjet Greater Than 3.5mm**: Indicate an "X" on the form. This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. *(This is considered an autoqualifying condition.)*
7. **Severe Maxillary Anterior Crowding, Greater Than 8mm**: Indicate an "X" on the form. *(This is considered an autoqualifying condition*.)
8. **Overjet in Millimeters:** This is recorded with the patient in the centric occlusion and measured from the labial of the lower incisor to the labial of the upper incisor. The measurement could apply to a protruding single tooth as well as to the whole arch. The measurement is read and rounded off to the nearest millimeter and entered on the form.
9. **Overbite in Millimeters**: A pencil mark on the tooth indicating the extent of overlap facilitates this measurement. It is measured

   should be measured and recorded.
10. **Mandibular Protrusion in Millimeters:** Score exactly as measured from the buccal groove of the first mandibular molar to the MB cusp of the first maxillary molar. The measurement in millimeters is entered on the form and multiplied by 5.
11. **Open Bite in Millimeters**: This condition is defined as the absence of occlusal contact in the anterior region. It is measured from edge to edge in millimeters. This measurement is entered on the form and multiplied by 4. In cases of pronounced protrusion associated with open bite, measurement of the open bite is not always possible. In those cases, a close approximation can usually be estimated.
12. **Ectopic Eruption:** Count each tooth, excluding third molars. Enter the number of teeth on the form and multiply by 3. If condition no. 13, anterior crowding, is also present, with an ectopic eruption in the anterior portion of the mouth, score only the most severe condition. Do not score both conditions.
13. **Anterior Crowding:** Arch length insufficiency must exceed 3.5 mm. Do not score mild rotations that may react favorably to stripping or mild expansion procedures. Enter 5 points for maxillary and mandibular anterior crowding. If condition no. 12, ectopic eruption, is also present in the anterior portion of the mouth, score the most severe condition. Do not score both conditions.
14. **Labio-Lingual Spread:** The measurement tool is used to determine the extent of deviation from a normal arch. Where there is only a protruded or lingually displaced anterior tooth, the measurement should be made from the incisal edge of that tooth to the normal arch line. Otherwise, the total distance between the most protruded tooth and the lingually displaced anterior tooth is measured. The labio-lingual spread probably comes close to a measurement of overall deviation from what would have been a normal arch. In the event that multiple anterior crowding of teeth is observed, all deviations from the normal arch should be measured for labio-lingual spread, but only the most severe individual measurement should be entered on the index.

    Additionally, anterior spacing may be measured as the total score in mm from the mesial of cuspid to the mesial of cuspid, totaling both arches.

    Enter only the highest score attained by any of the above methods.

The ABO Discrepancy Index (DI)
A Measure of Case Complexity

American Board of Orthodontics

Updated 04/[illegible]/2016

Target Disorders for Discrepancy Index

1. Overjet
2. Overbite
3. Anterior Open Bite
4. Lateral Open Bite

   Crowding

6. Occlusal Relationship

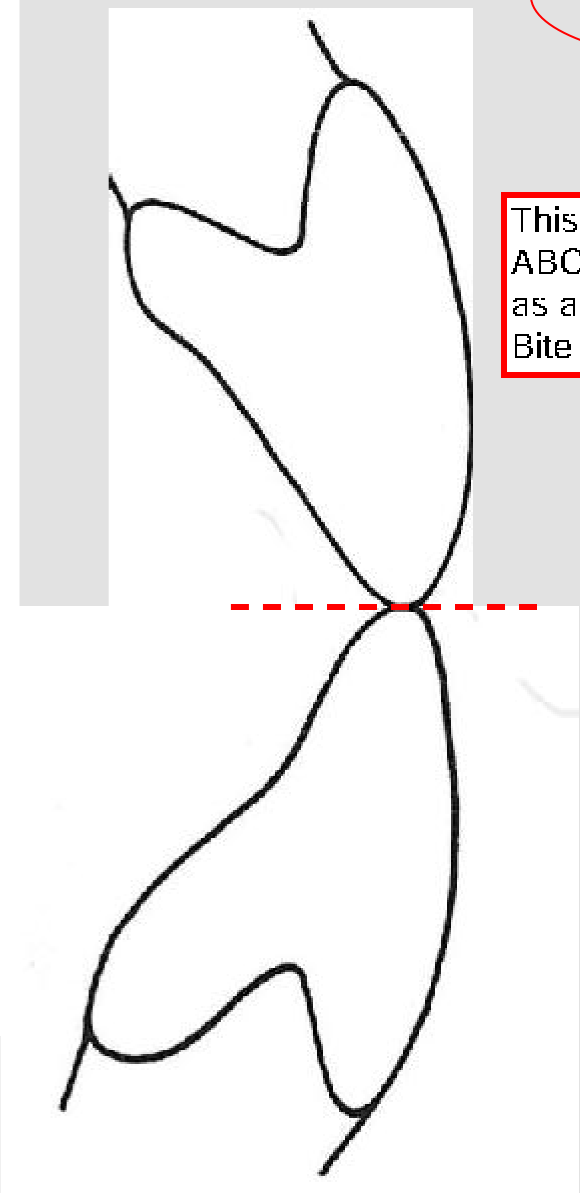
7. Lingual Posterior Crossbite

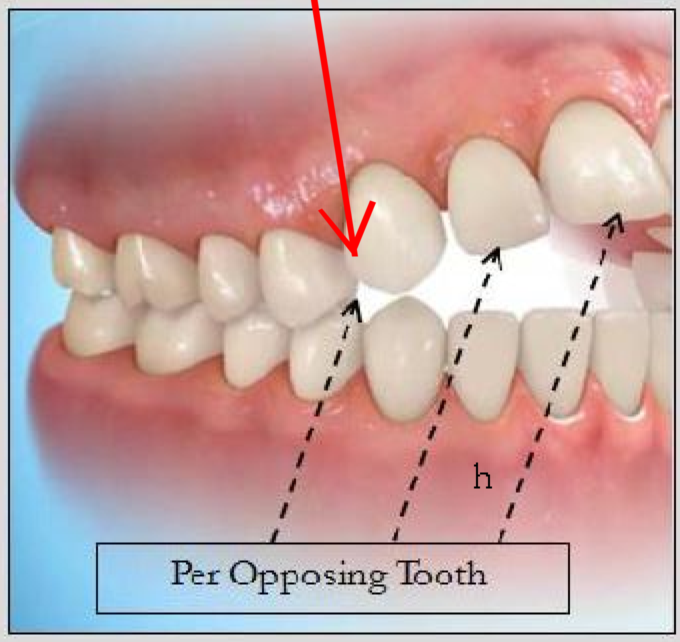
   Buccal Posterior Crossbite

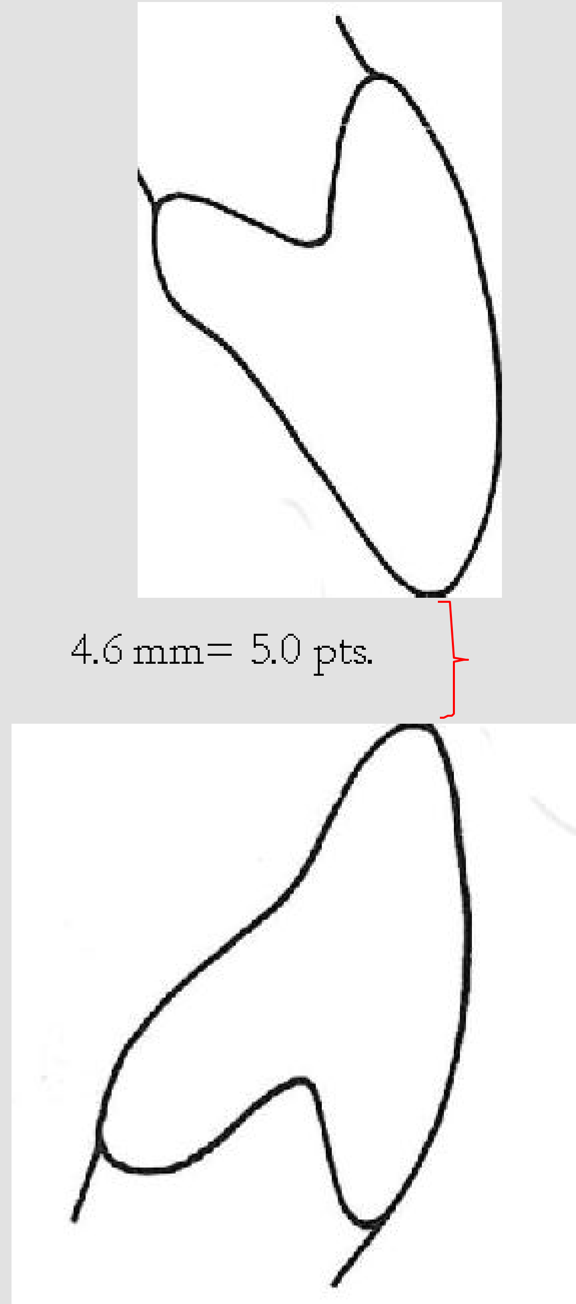
9. ANB Angle
10. SN-MP Angle
11. Lower Incisor to MP
12. Other

Anterior Open Bite Relationship

This is a Canine and the ABO points to the distal as an ANTERIOR Open Bite







For each anterior tooth in an edge to edge relationship (0 mm) score 1 pt per tooth. Then add for each anterior tooth in open bite (>1 mm) any fractional remainder to the next full mm 1 pt per mm per tooth in an open bite. No points are scored for any tooth that is blocked out of the arch due to space deficiency or not fully erupted.

other condition that would typically require the diagnosis, opinion, or expertise of a licensed clinician other than the requesting Provider, then the narrative and any attached documentation must:

i. clearly identify the appropriately qualified and licensed clinician(s) who furnished the diagnosis or opinion substantiating the condition or pathology (e.g., general dentist, oral surgeon, physician, clinical psychologist, clinical dietitian, speech therapist);
ii. describe the nature and extent of the identified clinician(s) involvement and interaction with the patient, including dates of treatment;
iii. state the specific diagnosis or other opinion of the patient's condition furnished by the identified clinician(s);
iv. document the recommendation by the clinician(s) to seek orthodontic evaluation or treatment (if such a recommendation was made);
v. discuss any treatments for the patient's condition (other than comprehensive orthodontic treatment) considered or attempted by the clinician(s); and
vi. provide any other relevant information from the clinician(s) that supports the requesting Provider's justification of the medical necessity of comprehensive orthodontic treatment.

The medical necessity narrative must be signed and dated by the requesting Provider and submitted on the office letterhead of the Provider, together with the required HLD Form and signed HLD Form Attestation. If applicable, any supporting documentation from the other involved clinician(s) must also be signed and dated by such clinician(s) and appear on office letterhead of such clinician(s). The requesting Provider is responsible for coordinating with the other involved clinician(s) and is responsible for compiling and submitting any supporting documentation furnished by other involved clinician(s) along with the medical necessity narrative.

16.2 Authorization Determination

The initial prior authorization approval for comprehensive orthodontics (D8080/D8070) and first two (2) years of treatment visits (D8670 x 8 units) will expire three (3) years from the date of the authorization. Approval for the third year of orthodontics will be valid for twelve to eighteen (12-18) months, depending on the number of units requested. Providers must check the patient's eligibility on each date of service to determine whether it will be an "eligible" service date.

If the case is denied, a determination notice will be sent to the member, and a separate courtesy notice will be sent to the provider along with the reviewer's worksheet indicating that the authorization for comprehensive orthodontic treatment has been denied. However, if a claim is sent in along with the prior authorization, a payment will be issued for code D8690 to cover the pre-orthodontic work-up, including the treatment plan, radiographs, diagnostic prints and/or photos orthodontic records, and diagnostic models.

1. If the prior authorization request is DENIED:

   a. DentaQuest will mail the member a denial notice. Additionally, DentaQuest will mail to the provider and post on the Provider Web Portal a separate courtesy notice and will mail the reviewer's worksheet to the provider.
   b. DentaQuest will issue a payment for code D8690 if a claim is sent in with the prior authorization to cover pre-orthodontic work-up that includes payment for any diagnostic radiographs or photographs and adjudicate using the date of service submitted on the authorization.
   c. Providers may request a second review of a denied prior authorization by submitting to DentaQuest in writing on the provider's office letterhead within thirty days from the date of the denial notice the following information:

      i. A detailed narrative of why the provider believes the prior authorization should have been approved, and
      ii. All documents originally submitted in addition to any new supporting documentation not previously submitted, including, as appropriate, radiographs, photographs, and letters or other documentation from other licensed clinicians involved in the membe treatment or otherwise knowledgeable about the membe condition.

2. If the prior authorization request is APPROVED:

Any reimbursement already made for an inadequate service may be recouped after the DentaQuest Consultant reviews the circumstances.

Orthodontics						
Code	**Description**	**Age Limitation**	**Teeth Covered**	**Authorization Required**	**Benefit Limitations**	**Documentation Required**
D8050	interceptive orthodontic treatment of the primary dentition	6-14		Yes	Adjustments for interceptive orthodontic treatment must be requested under the D8999 code and will be approved for a maximum of five units. Please see billing instructions in section 16 of the Office Reference Manual.	
D8060	interceptive orthodontic treatment of the transitional dentition	6-14		Yes	Adjustments for interceptive orthodontic treatment must be requested under the D8999 code and will be approved for a maximum of five units. Please see billing instructions in section 16 of the Office Reference Manual.	
D8070	comprehensive orthodontic treatment of the transitional dentition	6 - 20		Yes	One of (D8070, D8080) per 1 Lifetime Per patient. Only payable to a dental provider with a specialty of Orthodontics. Please see billing instructions in section 16 of the Office Reference Manual.	
D8080	comprehensive orthodontic treatment of the adolescent dentition	6 - 20		Yes	One of (D8070, D8080) per 1 Lifetime Per patient. Only payable to a dental provider with a specialty of Orthodontics. Please see billing instructions in section 16 of the Office Reference Manual.	
D8660	pre-orthodontic treatment examination to monitor growth and development	6 - 20		No	One of (D8660) per 6 Month(s) Per patient. Not billable after D8080,D8670, or D8680 has been paid. Only payable to a dental provider with a specialty of Orthodontics. Please see billing instructions in section 16 of the Office Reference Manual.	
D8670	periodic orthodontic treatment visit	6 - 20		Yes	One per 90 Day(s) Per patient. Allowed as quarterly treatment visits. May not be billed less than 90 days from previous periodic orthodontic treatment visit. (D8670). May not be billed less than 90 days from previous banding date. (D8080, D8070, D8090). May not be billed prior to D8080 / D8070 / D8090. Only payable to a dental provider with a specialty of Orthodontics. Please see billing instructions in section 16 of the Office Reference Manual.	

ORIGINAL ARTICLE CE AJO-DO

Incisor malalignment and the risk of periodontal disease progression

Ahmed A. Alsulaiman,[a] Elizabeth Kaye,[b] Judith Jones,[c] Howard Cabral,[d] Cataldo Leone,[e] Leslie Will,[f] and Raul Garcia[b]

Dammam, Saudi Arabia, Boston, Mass, and Detroit, Mich

Introduction: The objective of this study was to investigate the association between incisor crowding, irregularity, and periodontal disease progression in the anterior teeth. **Methods:** Data collected over 35 years from men enrolled in the Veterans Affairs Dental Longitudinal Study included information concerning pocket depth and alveolar bone loss. Plaster casts of the maxillary (n = 400) and mandibular (n = 408) arches were available for baseline measurements. Periodontal disease in the anterior teeth was de ned as per arch sum of pathologic pocket depth and sum of teeth with any alveolar bone loss in the anterior sextants. Incisor malalignment status was defined by the anterior tooth size-arch length discrepancy index and Little's Irregularity Index. Adjusted mixed effects linear models computed the beta (β) estimates and 95% confidence intervals (95% CI) of the amounts of change in periodontal disease outcomes by the level of malalignment. **Results:** In the anterior maxillary arch, crowding and spacing were signi cantly associated with an increased per-arch sum of pathologic pocket depth (β, 0.70 mm; 95% CI, 0.20-1.21, and β, 0.49 mm; 95% CI, 0.06-0.91, respectively). In the anterior mandibular arch, incisor crowding and irregularity were significantly associated with an increased per-arch sum of pathologic pocket depth (mild crowding: β, 0.47 mm; 95% CI, 0.01-0.93; severe irregularity: β, 0.94 mm; 95% CI, 0.50-1.38), and the sum number of teeth with alveolar bone loss (mild and moderate-to-severe crowding: β, 0.45 teeth; 95% CI, 0.08-0.82; and β, 0.45 teeth; 95% CI, 0.13-0.83, respectively; moderate irregularity: β, 0.34 teeth; 95% CI, 0.06-0.62). **Conclusions:** Certain incisor malalignment traits (ie, maxillary incisor crowding, maxillary incisor spacing, mandibular incisor mild crowding, mandibular incisor moderate-to-severe crowding, mandibular incisor moderate irregularity, and mandibular incisor severe irregularity) are associated with significant periodontal disease progression. (Am J Orthod Dentofacial Orthop 2018;153:512-22)

Periodontal disease is a major public health concern globally.[1] In the United States, approximately 50% of the adult population (≥30 years) has periodontitis.[2-4] Several risk factors have been associated with periodontal disease, and modification of these factors has an important role in treatment planning and patient management.[1-5] However, because of the high prevalence of periodontitis and the importance of the identi cation and modification of risk factors, additional research is warranted.

One often-overlooked possible causative factor for periodontal disease is the malalignment of teeth. The mechanism by which dental irregularity and crowding affect periodontal health is intuitive because dental

[a]Department of Preventive Dental Sciences, College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia; Department of Orthodontics and Dentofacial Orthopedics, Henry M. Goldman School of Dental Medicine, Boston University, Boston, Mass.
[b]Department of Health Policy and Health Service Research, Henry M. Goldman School of Dental Medicine, Boston University, Boston, Mass.
[c]School of Dentistry, University of Detroit Mercy, Detroit, Mich.
[d]Department of Biostatistics, School of Public Health, Boston University, Boston, Mass.
[e]Department of Periodontology, Henry M. Goldman School of Dental Medicine, Boston University, Boston, Mass.
[f]Department of Orthodontics and Dentofacial Orthopedics, Henry M. Goldman School of Dental Medicine, Boston University, Boston, Mass.

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
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Address correspondence to: Ahmed A. Alsulaiman, Department of Orthodontics and Dentofacial Orthopedics, Henry M. Goldman School of Dental Medicine, Boston University, 100 E Newton St, 708, Boston, MA 02118-2308; e-mail, Abalsulaiman@iau.edu.sa.
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irregularity and crowding offer a poor environment for maintaining periodontal health and cause harm to the periodontal tissues due to food retention and subsequent plaque accumulation.[7] This plausible mechanism typically exists in the maxillary and mandibular incisor segments.[8,9]

Periodontal disease is a localized disease,[10] and crowding or irregularity is greater in the anterior area.[11] In the current literature, results from early cross-sectional studies that investigated the association between periodontal disease parameters and anterior irregularity or crowding were often controversial because of several factors: (1) the use of invalid indexes to measure periodontitis and malalignment (eg, composite indexes), (2) difficulty in differentiating between crowding and irregularity, and (3) large statistical variability caused by a small sample size.[8,9,11-18] One cohort study showed no significant association between incisor irregularity and either pocket depth or bone loss.[19] This study had several limitations, including a short follow-up period (140 days), small sample size (n = 50) of dental students, and the use of neither reliable nor validated methods in measuring irregularity. Although the authors of this study attempted to investigate the association between incisor irregularity and periodontal disease, its limitations did not fill the gaps in the current knowledge of identifying whether irregularity or crowding is a true risk factor for periodontal disease.

Identifying irregularity and crowding as risk factors for periodontal disease may prioritize orthodontic treatment as a preventive measure over its esthetic or functional indicators. However, this action is not easily accomplished because periodontal disease advances intermittently or in bursts.[10,20] To overcome these obstacles in recognizing risk factors for periodontal disease, a longitudinal study design is needed with a long follow-up time and a relatively large sample. To the best of our knowledge, the associations between incisor irregularity, crowding, and periodontal disease have not been evaluated in a longitudinal study with a long-term follow-up. Therefore, the objective of this retrospective cohort study was to investigate the association between incisor crowding, irregularity, and periodontal disease progression using rigorous longitudinal analyses.

MATERIAL AND METHODS

In 1969, the Department of Veterans Affairs (VA) started a closed-panel dental longitudinal study by enrolling 1231 mostly white, medically healthy, community-dwelling male veterans drawn from the parallel VA Normative Aging Study. The participants had their medical and dental treatments in the private sector and were not patients of the VA care system. The first examination at which plaster casts were consistently made began in 1971. Thereafter, periodontal examinations were conducted approximately every 3 years (triennial examination) from 1971 to 2009 (total of 12 examinations). The inclusion criteria included participants who attended at least 3 examinations between 1971 and 2009, were completely dentate in the anterior sextants at baseline (1971), had measurable baseline plaster casts, and had not undergone orthodontic treatment. A retrospective sample of 400 maxillary and 408 mandibular plaster casts was available for measurements and longitudinal analysis. Mean follow-up times for subjects with maxillary and mandibular plaster casts were 23.7 ± 8.4 years and 23.5 ± 8.5 years, respectively (range, 9-36 years). All participants gave their informed consent before each examination. The study was approved by institutional review boards at Boston University Medical Center (Boston, Mass) and the VA Boston Healthcare System (Boston, Mass). This report complies with STROBE guidelines for observational studies.

At every triennial examination, calibrated periodontists performed a clinical and radiographic dental examination on all teeth and, when applicable, recorded the absence of teeth. Pocket depth and alveolar bone loss (ABL) data, limited to the anterior sextants (maxillary and mandibular central and lateral incisors and canines), were evaluated. A Williams probe (Hu-Friedy, Chicago, Ill) was used to obtain the maximum pocket depth (mesial, distal, labial, and lingual) per tooth and recorded on an interval score scale (score 1, 0-3 mm; score 2, >3-5 mm; score 3, >5 mm). The interval score scale was transformed to a continuous variable of pathologic pocket depth (PPD) in millimeters per tooth by using the midpoint of each recorded pathologic category (score 2, 4 mm; score 3, 6 mm).[21] Afterward, the PPD in millimeters per tooth was summed per arch segment (anterior maxillary and mandibular sum of PPD).[21] Periapical radiographs were taken with a paralleling method with Rinn holders. ABL was measured with a modified Schie score,[22] which superimposed a translucent ruler on the radiograph with assigned reference points at the cementoenamel junction and root apex. ABL scoring was done in the interproximal sites in 20% increments (score 0, no bone loss; score 1, bone loss ≤20%; score 2, bone loss >20% to ≤40%; score 3, bone loss >40% to ≤60%, score 4, bone loss >60% to ≤80%, score 5, bone loss >8,%). For ABL, the interval score scale was transformed into a continuous variable by calculating the total number of teeth with any bone loss (ABL score 1 or higher) per arch segment.[21] Based on repeated

Table I. Distribution of maxillary incisor crowding by selected characteristics for study participants at baseline (n = 400)

Characteristic	*Spacing: >0 mm (n = 192)*	*Ideal alignment: 0 mm (n = 117)*	*Crowding: <0 mm (n = 91)*
Age (y), mean ± SD	49.4 ± 7.6	49.4 ± 7.3	49.4 ± 7.2
Number of teeth remaining, mean ± SD	24.1 ± 2.9*†	24.9 ± 2.9	25.1 ± 2.2
Number of medications used, mean ± SD	1.5 ± 1.4	1.5 ± 2.9	1.6 ± 1.5
Baseline income (%)‡			
≤$14,999	34.6	31.3	37.9
$15,000-$24,999	48.1	47.8	49.4
≥$25,000	17.3	20.9	12.6
Educational level (%)‡			
High school or some college	30.7	22.2	24.2
College graduate	69.3	77.8	75.8
Smoking status (%)			
Nonsmoker	68.8	69.2	69.2
Smoker	31.2	30.8	30.8
Flossing frequency (%)			
Never	44.3	41.9	42.9
At least once monthly	55.7	58.1	57.1
Brushing frequency (%)‡			
Once a week or less	32.5	36.8	53.9
Twice a week of more	67.5	63.2	46.1
Saliva (%)‡			
Limited	19.8	11.1	26.4
Copious	80.2	88.9	73.6
Prophylaxis in past year (%)	66.2	66.7	70.3
Gum treatment in the past year (%)	6.8	6.8	6.6
Maxillary anterior plaque index, mean ± SD	7.6 ± 3.7	7.4 ± 3.5	7.6 ± 3.5
Maxillary anterior calculus index, mean ± SD	3.8 ± 4.4*	3.2 ± 4.0	4.0 ± 4.0*
Maxillary anterior mobility, mean ± SD	0.8 ± 2.0*†	0.6 ± 1.5	0.4 ± 1.2*
Maxillary anterior sum of PPD, mean ± SD	2.1 ± 3.9*	1.0 ± 2.0	2.2 ± 3.7*
Maxillary anterior sum number of teeth with bone loss, mean ± SD	2.0 ± 2.2*	1.8 ± 2.1	2.0 ± 2.3

*Different from ideal alignment, $P < 0.05$, based on analysis of variance.
†Different from crowding, $P < 0.05$, based on analysis of variance.
‡Difference between the levels of alignment, $P < 0.05$, based on the chi-square statistic.

assessments, reproducibility of pocket depth and ABL scores indicated good reliability (>0.4 kappa statistics) in 24 participants and 25 participants, respectively.[31] More detailed descriptions on the reproducibility of periodontal measures in the dental longitudinal study data have been reported previously.[35,37]

In addition, after the teeth were rinsed with a disclosing agent, an ordinal scale was used to record plaque (score 0, none; score 1, interproximal surfaces only; score 2, interproximal surfaces continuing onto labial or lingual sites; score 3, all surfaces covering more than two-thirds of the tooth). Supragingival calculus was measured by an ordinal scale (score 0, none; score 1, discontinuous flecks; score 2, noncontinuous band on tooth surfaces; score 3, continuous band on tooth surfaces). Instrument handles were used to assess mobility by pressing on the buccal and lingual surfaces of the tooth, and movement was scored by an ordinal scale (score 0, none; score 1, <0.5 mm; score 2, 0.5-1.0 mm; score 3, > 1.0 mm). For each anterior sextant, we calculated the mean plaque, calculus, and mobility scores.

Plaster dental casts obtained at baseline were used to measure incisor crowding and irregularity in the anterior maxillary and mandibular arches. In each arch, the space available minus the space required represented the amount of anterior dental crowding, as per the anterior tooth size-arch length discrepancy index.[36] Space required was obtained by the sum of the maximum mesiodistal widths of anterior teeth, canine to canine, using a digital caliper (maximum error, 0.02 mm; Pro-Max Electronic Digital Caliper; Fowler High Precision, Newton, Mass). Available space was determined through the arch best fit using a flexible ruler from the maximum point of the canines distally. The exible ruler was placed on the incisor surfaces of each arch, and the arch best t was identified as the even curve accommodating most teeth. When an equal number of anterior teeth were displaced in a different manner (eg, 3 anterior teeth

Table II. Distribution of maxillary incisor irregularity by selected characteristics of the study participants at baseline (n = 400)

Characteristics	*No-to-mild: ≥0 but <4 mm (n = 272)*	*Moderate: ≥4 but ≤6 mm (n = 81)*	*Severe: >6 mm (n = 47)*
Age (y), mean ± SD	49.3 ± 7.8	50.3 ± 7.0[*]	48.2 ± 8.1[*†]
Number of teeth remaining, mean ± SD	24.5 ± 2.7	24.6 ± 2.9	24.6 ± 2.9
Number of medications used, mean ± SD	1.5 ± 1.5	1.6 ± 1.5[*]	1.6 ± 1.5
Baseline income (%)[‡]			
≤$14,999	35.9	31.7	30.2
$15,000-$24,999	46.4	58.2	41.9
≥$25,000	17.7	10.1	27.9
Educational level (%)[‡]			
High school or some college	26.1	25.9	31.9
College graduate	73.9	74.1	68.1
Smoking status (%)			
Nonsmoker	68.8	70.4	68.1
Smoker	31.3	29.4	31.9
Flossing frequency (%)[‡]			
Never	43.8	38.3	48.9
At least once a month	56.2	61.7	51.1
Brushing frequency (%)			
Once a week or less	38.4	37.0	42.6
Twice a week of more	61.6	63.0	57.4
Saliva (%)[‡]			
Limited	17.6	22.2	19.1
Copious	82.4	77.8	80.9
Prophylaxis in past year (%)[‡]	65.8	66.7	76.7
Gum treatment in the past year (%)[‡]	8.1	1.2	8.5
Maxillary anterior plaque index, mean ± SD	7.3 ± 3.6	7.7 ± 3.5[*]	8.3 ± 3.4[*†]
Maxillary anterior calculus index, mean ± SD	3.4 ± 4.2	4.5 ± 4.6[*]	3.5 ± 3.2[†]
Maxillary anterior mobility, mean ± SD	0.7 ± 1.7	0.6 ± 1.4	0.6 ± 1.9
Maxillary anterior sum of PPD, mean ± SD	1.7 ± 3.1	2.1 ± 4.2[*]	2.0 ± 3.4
Maxillary anterior sum number of teeth with bone loss, mean ± SD	1.9 ± 2.2	2.0 ± 2.1	2.1 ± 2.3

*Different from no-to-mild category, $P < 0.05$, based on analysis of variance.
†Different from Moderate category, $P < 0.05$, based on analysis of variance.
‡Difference between the levels of alignment, $P < 0.05$, based on the chi-square statistic.

displaced labially, and 3 anterior teeth displaced lingually), a midpoint curve was used as a guide for the arch best fit. The severity of incisor crowding was categorized using the Index of Orthodontic Treatment Need (spacing, >0 mm; ideal alignment, 0 mm; mild crowding, <0 to ≥ −2 mm; moderate-to-severe crowding, < −2 mm).[15] In the maxillary arch, any crowding less than 0 mm was grouped into 1 category because of the limited number of severe cases. Incisor irregularity was determined by using Little's Irregularity Index, which defines irregularity as the labiolingual linear displacement of anatomic contact points obtained with a digital caliper placed parallel to the occlusal plane.[10] The severity of incisor irregularity was modified into 3 categories (no-to-mild irregularity, ≥0 to <4 mm; moderate irregularity, ≥4 to ≤6 mm; severe irregularity, >6 mm).[10] Changes in incisor crowding and irregularity status over time in the maxillary and mandibular arches were not statistically signi cant as tested ($P > 0.05$; paired t test) in a convenience sample of 39 subjects (paired t test power, 90%) who had 9 to 10 years of follow-up casts after the baseline records. After an interval of 4 weeks between measurements, intrarater reliability of more than 10% of randomly selected dental casts showed excellent interclass correlations greater than 0.98 for all 4 predictors (maxillary incisor crowding, mandibular incisor crowding, maxillary incisor irregularity, and mandibular incisor irregularity). All measurements were made by the same author (A.A.A.), who was trained by a board-certi ed orthodontist (L.W.).

Covariates included age in years, baseline income level (low, <$20,000; middle, ≥$20,000 to <$30,000; high, ≥$30,000), educational level (high school or some college, college graduate), smoking status (yes or no), number of medications, flossing (never or at least once a month), brushing (once a week or less, twice a week or more), quality and quantity of saliva (limited, copious), any gum treatment in the past year (yes or

Table III. Distribution of mandibular incisor crowding by selected characteristics of the study participants at baseline (n = 408)

Characteristics	*Spacing: >0 mm (n = 96)*	*Ideal alignment: 0 mm (n = 76)*	*Mild crowding: ≥–2 but <0 mm (n = 135)*	*Moderate-to-severe crowding: <–2 mm (n = 101)*
Age (y), mean ± SD	49.5 ± 7.5*	47.9 ± 7.8	50.0 ± 8.0*	50.0 ± 7.3*
Number of teeth remaining, mean ± SD	24.2 ± 3.1*‡	24.6 ± 3.0	24.4 ± 2.7	24.9 ± 2.6*†
Number of medications used, mean ± SD	1.7 ± 1.7†	1.5 ± 1.4	1.3 ± 1.4*	1.6 ± 1.5†
Baseline income (%)§				
≤$14,999	34.4	29.7	37.9	32.6
$15,000-$24,999	50.0	47.3	47.7	48.0
≥$25,000	15.6	23.0	14.4	19.4
Educational level (%)§				
High school or some college	29.2	27.6	28.9	19.8
College graduate	70.8	72.4	71.1	80.2
Smoking status (%)§				
Nonsmoker	63.5	64.5	72.6	72.3
Smoker	36.5	35.5	27.4	27.7
Flossing frequency (%)§				
Never	51.0	39.5	45.9	36.6
At least once a month	49.0	60.5	54.1	63.4
Brushing frequency (%)§				
Once a week or less	37.5	38.2	35.1	41.6
Twice a week of more	62.5	61.8	64.9	58.4
Saliva (%)§				
Limited	25.0	13.2	13.3	24.8
Copious	75.0	86.8	86.7	75.2
Prophylaxis in past year (%)§	72.9	61.8	68.9	65.4
Gum treatment in the past year (%)§	7.3	2.6	8.9	6.9
Mandibular anterior plaque index, mean ± SD	10.8 ± 3.3*†‡	11.3 ± 3.4	11.9 ± 3.5*	12.4 ± 3.2*†
Mandibular anterior calculus index, mean ± SD	8.7 ± 4.7*†‡	9.5 ± 5.0	9.9 ± 4.3	10.1 ± 4.1*
Mandibular anterior mobility, mean ± SD	0.5 ± 1.7*†‡	0.1 ± 0.6	0.3 ± 1.2*	0.1 ± 0.6†
Mandibular anterior sum of PPD, mean ± SD	1.4 ± 3.2	1.1 ± 2.3	1.5 ± 2.9*	1.5 ± 2.5*
Mandibular anterior sum number of teeth with bone loss, mean ± SD	3.2 ± 2.4*†‡	2.8 ± 2.3	3.4 ± 2.2*	3.5 ± 2.3*

*Different from ideal alignment, P <0.05, based on analysis of variance.
†Different from mild crowding, P <0.05, based on analysis of variance.
‡Different from moderate-to-severe crowding, P <0.05, based on analysis of variance.
§Difference between the levels of alignment, P <0.05, based on the chi-square statistic.

no), any prophylaxis cleanings in the past year (yes or no), number of teeth remaining in each anterior arch, and number of teeth remaining in the whole mouth.

Statistical analysis

All statistical analyses were conducted using software (version 9.4; SAS, Cary, NC). Analysis of variance with post hoc Tukey and chi-square tests were used in the bivariate analysis to identify any statistical association between baseline characteristics and malalignment traits as evaluated by Little's Irregularity Index and tooth size-arch length discrepancy. Multivariate linear mixed effects models were used to estimate the effect of incisor irregularity and crowding (Little's Irregularity Index and tooth size-arch length discrepancy) on the progression of periodontitis (sum of PPD in millimeters and number of teeth with ABL) in each arch. Correlated outcome data were controlled for by using a repeated-measure model with an autoregressive within-subject correlation matrix and a time factor (examination cycle) to cluster the observations. Confounders were included if they were signi cant at a 0.05 level or if they altered the coef cient of the main variable by more than 10% when the main association was signi cant. Statistical significance was evaluated at the 0.05 level.

RESULTS

The unit of analysis was each anterior sextant separately (anterior maxillary arch and anterior mandibular arch). For all 4 predictors, in general, participants were self-motivated and healthy white men in their sixth decade, mostly college educated, with an income category between $15,000 and $24,999; and had no smoking habits, fairly adequate flossing and brushing

Table IV. Distribution of mandibular incisor irregularity by selected characteristics of the study participants at baseline (n = 408)

Characteristics	*No-to-mild: ≥0 but <4 mm (n = 205)*	*Moderate: ≥4 but ≤6 mm (n = 132)*	*Severe: >6 mm (n = 71)*
Age (y), mean ± SD	50.0 ± 7.7	50.5 ± 7.7*	49.3 ± 7.6†
Number of teeth remaining, mean ± SD	24.4 ± 2.8	24.5 ± 3.1	24.7 ± 2.8*
Number of medications used, mean ± SD	1.5 ± 1.5	1.5 ± 1.4	1.5 ± 1.5
Baseline income (%)‡			
≤$14,999	30.9	38.7	36.9
$15,000-$24,999	49.3	50.8	48.1
>$25,000	19.9	10.5	15
Educational level (%)‡			
High school or some college	29.8	25.0	23.5
College graduate	70.2	75.0	76.5
Smoking status (%)‡			
Nonsmoker	65.4	70.5	73.0
Smoker	34.6	29.5	27.0
Flossing frequency (%)‡			
Never	47.3	40.2	42.2
At least once a month	52.7	59.8	57.8
Brushing frequency (%)			
Once a week or less	36.8	39.4	38.8
Twice a week of more	63.7	60.6	61.2
Saliva (%)‡			
Limited	18.5	17.4	19.4
Copious	81.5	82.6	80.6
Prophylaxis in past year (%)‡	65.4	75.8	69.9
Gum treatment in the past year (%)	6.8	7.6	7.1
Mandibular anterior plaque index, mean ± SD	11.1 ± 3.7†	11.9 ± 3.2*	12.6 ± 3.2*†
Mandibular anterior calculus index, mean ± SD	9.3 ± 4.7	9.6 ± 4.5	10.5 ± 4.3*†
Mandibular anterior mobility, mean ± SD	0.2 ± 1.1	0.4 ± 1.3*	0.3 ± 1.3†
Mandibular anterior sum of PPD, mean ± SD	1.2 ± 2.4	1.4 ± 2.9*	1.5 ± 2.9*
Mandibular anterior sum number of teeth with bone loss, mean ± SD	3.0 ± 2.3	3.6 ± 2.1*	3.4 ± 2.3*†

*Different from no-to-mild category, P <0.05, based on analysis of variance.
†Different from moderate category, P <0.05, based on analysis of variance.
‡Difference between the levels of alignment, P <0.05, based on the chi-square statistic.

practices, copious amount of saliva, and high prophylaxis treatment in the past year. Anterior sum plaque and calculus scores were higher in the mandibular anterior arch (11.6 ± 3.4 and 9.7 ± 4.5, respectively) than in the maxillary anterior arch (7.4 ± 3.6 and 3.8 ± 4.3, respectively). Anterior mobility scores were higher in the anterior maxillary arch (0.7 ± 1.7) than in the anterior mandibular arch (0.3 ± 1.3). Periodontal health outcomes in the anterior maxillary arch showed the following variations: the sum of the PPD varied from 0 to 18 mm (mean, 1.9 ± 3.5 mm), and the sum number of teeth with ABL varied from 0 to 6 (mean, 2.0 ± 2.2). Periodontal health outcomes in the anterior mandibular arch showed the following variations: the sum of the PPD varied from 0 to 17 mm (mean, 1.4 ± 2.8 mm), and the sum number of teeth with ABL varied from 0 to 6 (mean, 3.2 ± 2.3). Baseline characteristics by crowding and irregularity status of the study sample are given in Tables I through IV.

Repeated-measure mixed effects linear multivariate models of the longitudinal association between periodontal disease outcomes (sum of PPD and sum of the number of teeth with ABL) and maxillary incisor crowding and irregularity status are summarized in Tables V and VI. After controlling for related covariates, compared with ideal alignment, the results showed that maxillary anterior arches with incisor crowding and spacing had a significantly greater mean sum of anterior PPD (β, 0.70 mm; 95% CI, 0.20-1.21; and β, 0.49 mm; 95% CI, 0.06-0.91, respectively) (Table V). Maxillary anterior arches with incisor crowding and spacing were not significantly associated with sums of the number of teeth with ABL (Table V). Maxillary anterior incisor irregularity was not significantly associated with the sum of the PPD or the sum of the number of teeth with ABL (Table VI).

For the analysis of the association between periodontal disease outcomes (sum of PPD and sum of the

Table V. Unadjusted and adjusted mixed effects estimates and 95% confidence intervals of the association between maxillary incisor crowding and anterior sum of PPD and the number of teeth with ABL (n = 400)

	Crowding status beta estimate (95% CI)				
	Categorical variables				
	Spacing (n = 192)		*Ideal (n = 117)*	*Crowding (n = 91)*	
Periodontal disease outcome	*Unadjusted*	*Adjusted*†	*Reference*	*Unadjusted*	*Adjusted*†
Anterior maxillary sum of PPD	0.84* (0.34-1.34)	0.49* (0.06-0.91)	0	0.98* (0.39-1.57)	0.70* (0.20-1.21)
Anterior maxillary sum number of teeth with bone loss	0.01 (0.34 to 0.36)	−0.00 (−0.31 to 0.30)	0	0.15 (−0.27 to 0.57)	0.11 (−0.25 to 0.48)

*P <0.05.
†Model adjusted for age, maxillary anterior plaque score, maxillary anterior calculus score, maxillary anterior mobility score, college education (yes/no), smoking (yes/no), flossing (never/ever), brushing (≤1 time a day/≥2 times a day), prophylaxis treatment in the last year (yes/no), gum treatment in the last year (yes/no), baseline income (low, ≤$14,999; middle, $15,000-$24,999; high, ≥$25,000), and number of remaining teeth in the anterior arch.

Table VI. Unadjusted and adjusted mixed effects estimates and 95% confidence intervals of the association between maxillary incisor irregularity and anterior sum of PPD and number of teeth with ABL (n = 400)

	Irregularity status beta estimate (95% CI)				
	Categorical variables				
	No-to-mild (n = 272)	*Moderate (n = 81)*		*Severe (n = 47)*	
Periodontal disease outcome	*Reference*	*Unadjusted*	*Adjusted**	*Unadjusted*	*Adjusted**
Anterior maxillary sum of PPD	0	0.25 (0.29 to 0.79)	0.06 (0.39 to 0.52)	0.13 (0.50 to 0.84)	0.21 (−0.37 to 0.79)
Anterior maxillary sum number of teeth with bone loss	0	0.17 (0.21 to 0.54)	0.07 (0.25 to 0.41)	0.20 (0.28 to 0.67)	0.14 (0.27 to 0.56)

*Model adjusted for age, maxillary anterior plaque score, maxillary anterior calculus score, maxillary anterior mobility score, college education (yes/no), smoking (yes/no), ossing (never/ever), brushing (≤1 times a day/≥2 times a day), prophylaxis treatment in the last year (yes/no), gum treatment in the last year (yes/no), baseline income (low, ≤$14,999; middle, $15,000-$24,999; high, ≥$25,000), and number of remaining teeth in the anterior arch. CI, confidence interval.

number of teeth with ABL) and mandibular incisor crowding and irregularity status, the repeated-measure mixed-effects linear multivariate models are given in Tables VII and VIII. In general, the association between periodontal disease outcomes was more distinct in the mandibular arch than in the maxillary arch. After controlling for other confounders, compared with ideal alignment, mild incisor crowding in the mandibular arch was significantly associated with a greater anterior sum of the PPD (β, 0.47 mm; 95% CI, 0.01-0.93). Although the beta coef cient for moderate-to-severe incisor crowding in the mandibular arch was the same as in the mild group, the statistical signi cance was borderline (β, 0.47 mm; 95% CI, −0.02 to 0.96) (Table VII). Multivariate analysis controlling for other confounders showed that mild and moderate-to-severe incisor crowding in the mandibular arch had signi cant positive associations with the sum of the number of teeth with ABL, compared with ideal alignment (β, 0.45 teeth; 95% CI, 0.08-0.82; and β, 0.45 teeth; 95% CI. 0.13-0.83, respectively) (Table VII). When we analyzed incisor irregularity in the mandibular arch, compared with no-to-mild incisor irregularity, the adjusted model showed that severe incisor irregularity was significantly associated with a greater anterior sum of the PPD (β, 0.94 mm; 95% CI, 0.50-1.38) (Table VIII). The repeated-measure mixed-effects ABL linear multivariate models in the anterior mandibular arch also indicated that, compared with no-to-mild incisor irregularity, moderate incisor irregularity had a significantly higher sum number of teeth with ABL (β, 0.34 teeth; 95% CI, 0.06-0.62) (Table VIII).

DISCUSSION

To the best of our knowledge, this study is the first to rigorously test the longitudinal association between incisor crowding and irregularity with per-arch anterior-specific periodontal disease outcomes (anterior sum of PPD and sum number of teeth with ABL). Many studies have

SPACING EFFECTS

CROWDING EFFECTS

Table VII. Unadjusted and adjusted mixed effects estimates and 95% confidence intervals of the associations be[illegible] mand[illegible] incisor crowding and anterior sum of PPD and number of teeth with ABL (n = 408)

	Crowding status beta estimate (95% CI)						
	Categorical variables						
	Spacing (n = 96)		Ideal (n = 76)	Mild crowding (n = 135)		Moderate-to-severe crowding (n = 101)	
Periodontal disease outcome	Unadjusted	Adjusted	Reference	Unadjusted	Adjusted	Unadjusted	Adjusted
Anterior mandibular sum of PPD	0.12 [−0.47 to 0.71]	−0.08 [−0.59 to 0.42]	0	0.60* [0.05-1.14]	0.47* [0.01-0.93]	0.70* [0.08-1.23]	0.47 [−0.02 to 0.96]
Anterior mandibular sum of the number of teeth with bone loss	0.21 [−0.20 to 0.63]	0.24 [−0.14 to 0.63]	0	0.46* [0.08-0.85]	0.45* [0.13-0.83]	0.36 [−0.05 to 0.77]	0.45* [0.08-0.82]

*P <0.05.
Model adjusted for age, mandibular anterior plaque score, mandibular anterior calculus score, mandibular anterior mobility score, college education [yes/no], smoking [yes/no], flossing [never/ever], brushing [<1 times a day/>2 times a day], prophylaxis treatment in the last year [yes/no], gum treatment in the last year [yes/no], baseline income [low, <$14,999; middle, $15,000-$24,999; high, >$25,000], and number of remaining teeth in the anterior arch.

tested the association between incisor crowding or irregularity with several periodontal disease outcomes using an arch-specific analysis, but they often used invalid or unreliable methods to measure incisor crowding and irregularity.[6-11,15,31] Some investigators even used composite measures that combined incisor crowding and irregularity into 1 index, which may introduce misclassification bias resulting from differences between crowding and irregularity from a theoretical and clinical prospective.[6,11] Furthermore, the definitions of periodontal disease were often ambiguous and invalid, thereby hindering the ability to compare our results with previous studies.

We found that maxillary anterior spacing was associated with a significant increase in PPD in the anterior maxillary arch; this agrees with a cross-sectional study.[11] When we considered maxillary crowding, our study is the first valid demonstration that maxillary anterior crowding is significantly associated with a larger PPD. These results can be explained by greater food impaction with spacing and plaque accumulation in crowded arches.[4,11] The likelihood of primary or secondary occlusal trauma with flared anterior teeth in instances of spacing or crowding is another plausible explanation.[11,13] In addition, the maxillary anterior teeth have large roots and distinct cross-sectional shapes to withstand off-axis loading that may increase destructive lateral forces on their supporting periodontal structures.[11] ABL in the anterior maxillary area showed greater statistical variability and no significant association with incisor spacing or crowding. This may be primarily because the Schei scale measured ABL in large intervals of percentages of loss rather than millimeters.

Three other cross-sectional studies and 1 short longitudinal study examined the association between maxillary incisor irregularity and periodontal disease outcomes.[5,15,17,19] The well-accepted definition of incisor irregularity was introduced in 1975 by Little,[10] although no study used a singular validated and reliable method to account for irregularity.[5,15,17,19] Of these, the authors of only 1 study found a significant relationship between the numbers of irregular proximal surfaces in the anterior segment and the frequency of pocket depth on all tooth surfaces.[5] Our results were similar in showing a positive relationship, but without statistical significance. These differences were generally observed because of methodologic dissimilarities in pocket depth definition, the irregularity measurement, and the rigorous statistical testing in our study. Furthermore, the finding of no significant association between ABL and irregularity in the maxillary anterior area agreed with another longitudinal study.[19]

Table VIII. Unadjusted and adjusted mixed effects estimates and 95% confidence intervals of the associations between mandibular incisor irregularity and anterior sum of PPD and number of teeth with ABL (n = 408)

	Irregularity status beta estimate (95% CI)				
	Category				
	No-to-mild (n = 205)	*Moderate (n = 132)*		*Severe (n = 71)*	
Periodontal disease outcome	*Reference*	*Unadjusted*	*Adjusted*†	*Unadjusted*	*Adjusted*†
Anterior mandibular sum of PPD	0	0.02 (0.40 to 0.44)	-0.04 (−0.40 to 0.32)	0.97* (0.45-1.49)	0.10* (0.02-0.19)
Anterior mandibular sum number of teeth with bone loss	0	0.32* (0.02-0.63)	0.34* (0.06-0.62)	0.07 (−0.30 to 0.44)	0.05 (−0.01 to 0.11)

*P <0.05.
†Model adjusted for age, maxillary anterior plaque score, maxillary anterior calculus score, maxillary anterior mobility score, college education (yes/no), smoking (yes/no), flossing (never, ever), brushing (≤1 times a day/≥2 times a day), prophylaxis treatment in the last year (yes/no), gum treatment in the last year (yes/no), baseline income (low, ≤$14,999; middle, $15,000-$24,999; high, ≥$25,000), and number of remaining teeth in the anterior arch.

Our sample of participants exhibited much more distinct localized periodontal disease progression in association with crowding or irregularity in the mandibular incisor area. This finding has several reasons: (1) our sample had much more severe crowding and irregularity in the mandibular incisors; (2) the bone plate is thinnest in this area, particularly on the labial surface[11]; (3) in this area, thin bone is often manifested as incomplete bony coverage (fenestration and dehiscence)[11]; (4) higher prevalence of root proximity was previously noted in the mandibular incisors,[15,16] which is a confirmed local risk factor for periodontal disease progression in the same dental longitudinal study data source[17]; and (5) the location of the mandibular incisors opposing the opening of salivary gland ducts may increase local inflammatory responses.[18] We report the first significant positive associations between mandibular incisor crowding (mild or moderate-to-severe) and PPD and ABL. Other studies investigating these associations were cross-sectional, used composite periodontal disease indexes, and questionably acceptable crowding measurements.[10, 11] Other than a short longitudinal study[19] with several limitations, including a short follow-up period, a small sample size (n = 50), lack of accounting for attachment loss, and use of neither reliable nor validated methods in measuring irregularity, this study is the first to demonstrate significant positive associations between mandibular incisor irregularity (moderate or severe) and both PPD and ABL. With regard to pocket depth in particular, 3 cross-sectional studies[9,11,17] agreed with our significant positive findings, whereas 2 studies[15,18] disagreed. Furthermore, 1 cross-sectional study[15] examining the association between ABL and mandibular incisor irregularity reported a similar significant positive relationship, whereas another cross-sectional study of children did not.[18]

The strengths of our study include the use of repeated-measure data with comprehensive dental examinations, many participants, long follow-up, and rigorous longitudinal statistical testing (adjusted mixed effects linear models). However, this study had several important limitations. The generalizability of the results of this cohort study is limited because most participants were white men, thereby limiting the ability to examine the effects of sex and race or ethnicity. In both arches, the severity of crowding was not great; this restricted our ability to observe the effect of severe crowding (>5 mm) on periodontal disease outcomes. Furthermore, our data did not include information regarding clinical attachment loss. Despite that, our analyses included 2 parameters (PPD, and ABL) that are considered adequate to define periodontal disease progression.[19] Underestimation is predicted in periodontal disease outcomes because our participants were limited to those who attended at least 3 triennial follow-ups, indicating that they may have had a greater interest in their oral health. Using a method founded by Dietrich et al,[21] PPD values were imputed from the midpoint of the original interval maximum pocket depth variable (score 2, 4 mm; score 3, 6 mm). These midpoint values are appropriate clinical assumptions (not true values) that correspond to the level of periodontal disease originally coded in the interval variable (mild periodontitis, 4 mm; moderate-to-severe periodontitis, 6 mm).[19] This statistical method is acceptable and frequently used to resolve the aggregation issues in data analysis.[11] In this study, ABL was reported as a percentile variable rather than as a millimeter change. This factor did not allow us to see much change in the ABL variable, compared with the millimeter changes in PPD.

CONCLUSIONS

This study is the first to provide evidence that certain malalignment traits (maxillary incisor crowding, maxillary incisor spacing, mandibular incisor mild crowding, mandibular incisor moderate-to-severe crowding, mandibular incisor moderate irregularity, and mandibular incisor severe irregularity) are risk factors in periodontal disease progression. General dentists should inform their patients about the impact of incisor malalignment (incisor crowding and irregularity) on periodontal health and provide appropriate orthodontic referrals. This study should also have a future impact on the practice of orthodontics from providing esthetic and functional treatments to engaging in preventive treatments by alleviating incisor malalignment.

ACKNOWLEDGMENT

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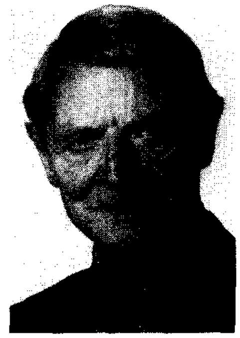
REFERENCES

1. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. Bull World Health Org 2005;83:661-9.
2. Eke PI, Dye BA, Wei L, Slade GD, Thornton-Evans GO, Borgnakke WS, et al. Update on prevalence of periodontitis in adults in the United States: NHANES 2009 to 2012. J Periodontol 2015;86:611-22.
3. Eke PI, Zhang X, Lu H, Wei L, Thornton-Evans G, Greenlund KJ, et al. Predicting Periodontitis at state and local levels in the United States. J Dent Res 2016;95:515-22.
4. Knight ET, Liu J, Seymour GJ, Faggion CM, Cullinan MP. Risk factors that may modify the innate and adaptive immune responses in periodontal diseases. Periodontol 2000 2016;71:22-51.
5. Genco RJ, Borgnakke WS. Risk factors for periodontal disease. Periodontol 2000 2013;62:59-94.
6. AlJehani YA. Risk factors of periodontal disease: review of the literature. Int J Dent 2014;2014:182513.
7. Hellgren A. The association between crowding of the teeth and gingivitis. Trans Eur Orthod Soc 1956;32:134-40.
8. Ainamo J. Relationship between malalignment of the teeth and periodontal disease. Eur J Oral Sci 1972;80:104-10.
9. Silness J, Roynstrand T. Relationship between alignment conditions of teeth in anterior segments and dental health. J Clin Periodontol 1985;12:312-20.
10. Jd B, Gd S. Epidemiology of periodontal diseases. Curr Opin Periodontol 1995;3:3-9.
11. Staufer K, Landmesser PD. Effects of crowding in the lower anterior segment—a risk evaluation depending upon the degree of crowding. J Orofac Orthop 2004;65:13-25.
12. Poulton DR, Aaronson SA. The relationship between occlusion and periodontal status. Am J Orthod 1961;47:690-9.
13. Buckley LA. The relationship between malocclusion and periodontal disease. J Periodontol 1972;43:415-7.
14. Geiger AM, Wasserman BH, Turgeon LR. Relationship of occlusion and periodontal disease part VIII—relationship of crowding and spacing to periodontal destruction and gingival inflammation. J Periodontol 1974;45:43-9.
15. Helm S, Petersen PE. Causal relation between malocclusion and periodontal health. Acta Odontol Scand 1989;47:223-8.
16. Jensen BL, Solow B. Alveolar bone loss and crowding in adult periodontal patients. Community Dent Oral Epidemiol 1989;17:47-51.
17. Ngom PI, Diagne F, Benoist HM, Thiam F. Intraarch and interarch relationships of the anterior teeth and periodontal conditions. Angle Orthod 2006;76:236-42.
18. Abu Alhaija ES, Al-Wahadni AM. Relationship between tooth irregularity and periodontal disease in children with regular dental visits. J Clin Pediatr Dent 2006;30:296-8.
19. Ingervall B, Jacobsson U, Nyman S. A clinical study of the relationship between crowding of teeth, plaque and gingival condition. J Clin Periodontol 1977;4:214-22.
20. Socransky SS, Haffajee AD, Goodson JM, Lindhe J. New concepts of destructive periodontal disease. J Clin Periodontol 1984;11:21-32.
21. Dietrich T, Jimenez M, Kaye E, Vokonas PS, Garcia RI. Age-dependent associations between chronic periodontitis/edentulism and risk of coronary heart disease. Circulation 2008;117:1668-74.
22. Schei O, Waerhaug J, Lovdal A, Arno A. Alveolar bone loss as related to oral hygiene and age. J. Periodontol 1959;30:7-16.
23. Ng N, Kaye EK, Garcia RI. Coffee consumption and periodontal disease in males. J Periodontol 2013;85:1042-9.
24. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159-74.
25. Glass RL, Loftus ER, Kapur KK, Alman JE. Analyses of components of periodontal disease. J Dent Res 1973;52:1238-44.
26. Feldman RS, Douglass CW, Loftus ER, Kapur KK, Chauncey HH. Interexaminer agreement in the measurement of periodontal disease. J Periodontal Res 1982;17:80-9.
27. Fleiss JL, Chilton NW. The measurement of interexaminer agreement on periodontal disease. J Periodontal Res 1983;18:601-6.
28. Harris EF, Vaden JL, Williams RA. Lower incisor space analysis: a contrast of methods. Am J Orthod Dentofacial Orthop 1987;92:375-80.
29. Proffit WR, Fields HW, Sarver DM. Contemporary orthodontics. 5th ed. St Louis: Mosby; 2013.
30. Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod 1975;68:554-63.
31. Jernberg GR, Bakdash MB, Keenan KM. Relationship between proximal tooth open contacts and periodontal disease. J Periodontol 1983;54:529-33.
32. Greenstein G, Cavallaro J, Scharf D, Tarnow D. Differential diagnosis and management of flared maxillary anterior teeth. J Am Dent Assoc 2008;139:715-23.
33. Misch CE. Contemporary implant dentistry. 3rd ed. St Louis: Mosby; 2008.
34. Clerehugh V, Tugnait A, Genco R. Periodontology at a glance. Chichester, United Kingdom: John Wiley & Sons; 2009.
35. Årtun J, Kokich VG, Osterberg SK. Long-term effect of root proximity on periodontal health after orthodontic treatment. Am J Orthod Dentofacial Orthop 1987;91:125-30.
36. Heins PJ, Thomas RG, Newton JW. The relationship of interradicular width and alveolar bone loss. A radiometric study of a periodontitis population. J Periodontol 1988;59:73-9.
37. Kim T, Miyamoto T, Nunn ME, Garcia RI, Dietrich T. Root proximity as a risk factor for progression of alveolar bone loss: the Veterans Affairs Dental Longitudinal Study. J Periodontol 2008;79:654-9.
38. Mandel ID. Calculus update: prevalence, pathogenicity and prevention. J Am Dent Assoc 1995;126:573-80.

39. Tonetti MS, Claffey N, European Workshop in Periodontology group C. Advances in the progression of periodontitis and proposal of definitions of a periodontitis case and disease progression for use in risk factor research. Group C consensus report on the 5th European Workshop in Periodontolgy. J Clin Periodontol 2005; 32(Suppl 6):210-3.
40. American Academy of Periodontology Task Force. Report on the update to the 1999 classification of periodontal diseases and conditions. J Periodontol 2015;86:835-8.
41. Powers D, Xie Y. Statistical methods for categorical data analysis. 2nd ed. Bingley, United Kingdom: Emerald Group Publishing; 2008.

Eruption of teeth into crowded position, loss of attachment, and downgrowth of subgingival plaque



Dr. Waerhaug

Jens Waerhaug
Oslo, Norway

The role of crowded teeth in the etiology of attachment loss was studied in thirty teeth extracted for orthodontic reasons from eight children 12 to 13 years of age. Following extraction, the teeth were stained in a 1 percent solution of water blue and examined under the stereomicroscope. In one third of the thirty teeth, a 0.9, 2.0, and 3.5 mm. loss of attachment was observed on surfaces adjacent to which another tooth had erupted into an extremely crowded environment. On the same surfaces, subgingival plaque had grown down to the area of the cementoenamel junction. The premature loss of attachment was assumed to be mediated by collagenase derived from the regressing dental organ or from the junctional epithelium surrounding the erupting teeth. The premature downgrowth of subgingival plaque to the area of the cementoenamel junction was facilitated by the development of an irregular contact line within the interdental papilla, rather than a contact point above the papilla.

Key words: Crowding, loss of attachment, subgingival plaque, periodontics

There are different opinions regarding the relationship between crowding of teeth, plaque, and gingival condition as well as destructive periodontal disease.[1] At least one report[2] has demonstrated a small but convincing correlation between malalignment and loss of attachment in 19- to 21-year-old men, but the report gave no clue to as to what had caused the destruction of the periodontal fibers.

The purpose of the present study was to determine why attachment is lost more rapidly adjacent to teeth in a crowded position than adjacent to normally aligned teeth.

Material and method

The observations were made on twenty-eight first premolars and two lateral incisors which were extracted in conjunction with orthodontic treatment in eight children aged 12 and 13 years. One or more weeks before the extractions all children had been given oral hygiene instruction, and immediately prior to the extractions the level of the gingival margin was marked on the tooth surface. The extracted teeth were rinsed in running water, stained for 10 minutes in a 1.0 percent solution of water blue, rinsed for another 10 minutes in running water, air-dried, and examined under the stereomicroscope at a magnification of $\times 10$ to $\times 40$.[3]

From the Department of Periodontics, School of Dentistry, University of Oslo.

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Table I. Distribution of surfaces with loss of attachment on the twenty-eight first premolars and the two lower lateral incisors included in the material

Surface	*Total No.*	*No. with loss of attachment*
Buccal	30	0
Distal	30	0
Lingual	30	0
Mesial	30	3
Total	120	3

*The areas of lost attachment, in square millimeters, were 0.9, 4.4, and 12.25, respectively.

Table II. Distance from plaque (or, in the absence of plaque, the gingival margin) to the cementoenamel junction on the various surfaces of the thirty teeth included in the material

Surface	*No.*	*Average (mm.) distance*	*Range*
Buccal	30	2.4 mm	1.1 – 5.0*
Distal	30	2.5 mm	2.2 – 3.5
Lingual	30	2.5 mm	1.8 – 4.6*
Mesial	30	2.4 mm	−0.5† – 3.4

*The high maximum distance is due to the fact that some of the premolars had only recently broken through.
†The negative sign signifies that the plaque had migrated below the cementoenamel junction in one case (Fig. 3, left). In the other two cases with loss of attachment, the plaque was found 0.2 and 0.4 mm. above the same reference line.

Observations

Clinical examination on the day of extraction revealed only minor amounts of visible plaque and basically healthy gingival conditions in all cases.

Loss of attachment or no loss of attachment was determined on the basis of the presence or absence of periodontal fibers attached to the cementum below the borderline of the enamel of the extracted teeth (Fig. 3, *left* and *right*). In Table I it may be seen that loss of attachment occurred on three of the 120 surfaces, and the areas of lost attachment were 0.9 by 1.0 mm., 2.0 by 2.2 mm., and 3.5 by 3.5 mm., respectively.

There was no subgingival plaque in 117 of the surfaces and the distance from any supragingival plaque to the cementoenamel junction varied between 1.7 and 5 mm. (Table II). Subgingival plaque had developed on three surfaces, and in one case it had even migrated below the cementoenamel junction (Fig. 3, *left*). In the remaining two cases, the plaque was found 0.2 and 0.4 mm. from the same reference line.

The loss of attachment and the downgrowth of subgingival plaque occurred on the same three teeth (two first premolars and one lateral incisor); common to all three teeth was the fact that a neighboring tooth (two second premolars and one canine) had erupted into a space that was altogether too narrow, with the consequence that a highly unfavorable contact relationship had been established (Figs. 1 and 2).

One of the patients with loss of attachment (the case shown in Figs. 2 and 3) was recalled 3½ months after extraction of the first premolars. There were no visible signs of gingivitis around any of the teeth, but probing of the pocket on the mesial surface of the lower first molar caused more than usual bleeding and pain. In the corresponding area the

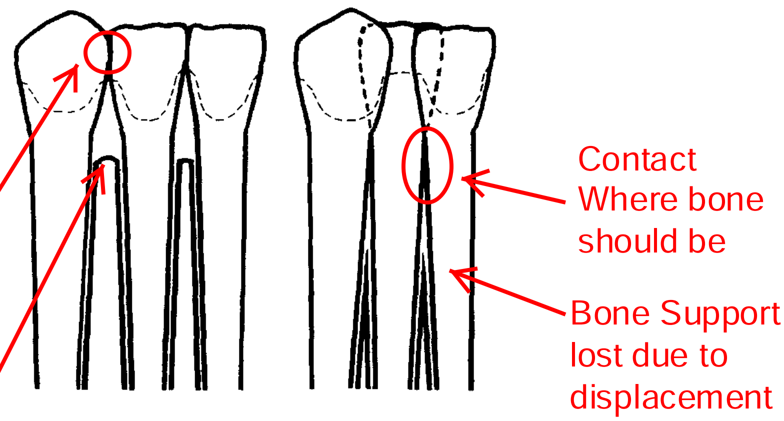

Fig. 1. Left: Schematic drawing to show normal relationship between front teeth in lower jaw. Contact point above tip of papilla. **Right:** Irregular contact relationship as existing between just erupted canine and lateral incisor mentioned in text. Rather than a contact point above the tip of the papilla, there was a contact line between the teeth from the gingival margin to the alveolar crest, leading to a split papilla.

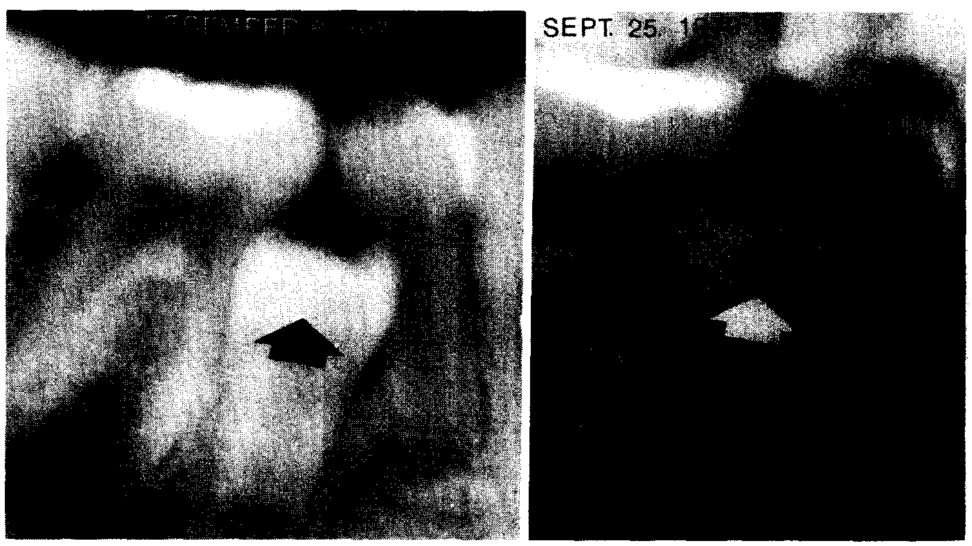

Fig. 2. Orthopanthomographs showing eruption of lower right second premolar. **Left:** Contact between latter and first molar as well as first premolar. **Right:** During a 10-month period the two teeth have been forced apart by the erupting second premolar, indicating direct contact between the three teeth.

roentgenograph revealed an angular bone defect (Fig. 4, *left*), and the penetration of a probe 4.5 mm. below the cementoenamel junction verified the loss of attachment (Fig. 5, *right*). There was no evidence of loss of attachment on the distal surface of the same tooth.

Discussion

The observation made on the distal surfaces of the two first premolars and the lateral incisor demonstrated that the eruption of a tooth into a very crowded environment may create two basically different conditions on the neighboring teeth: (1) a premature loss of

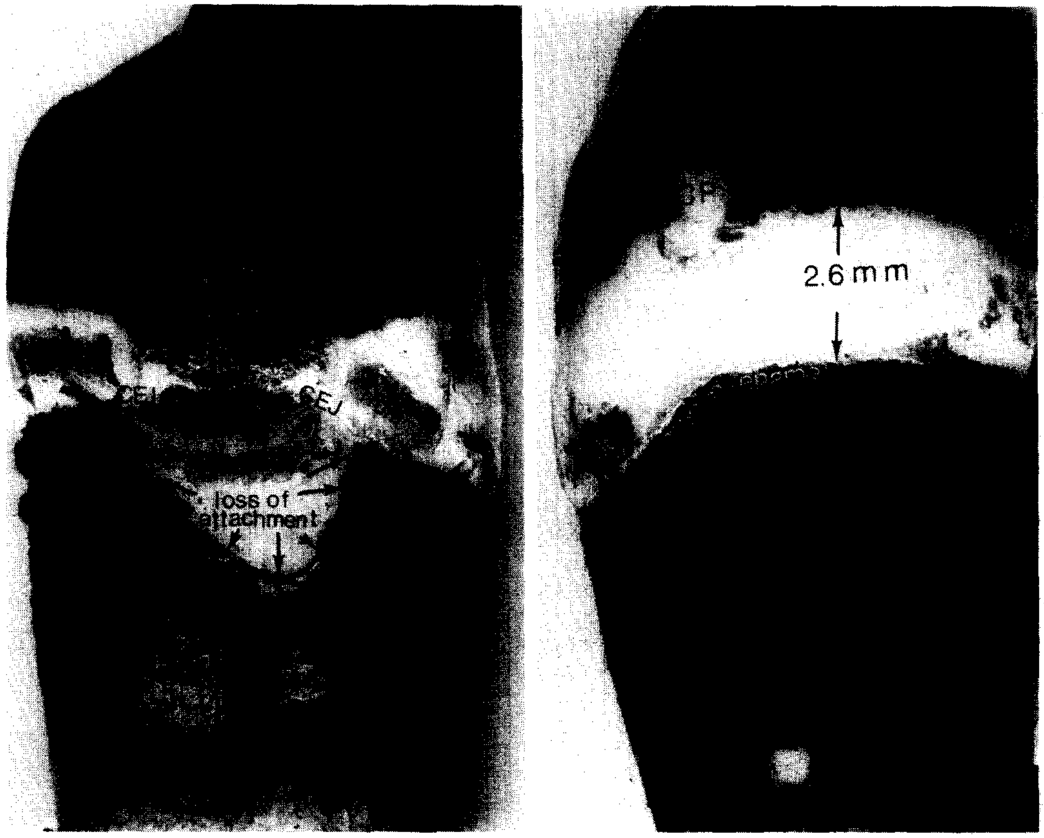

Fig. 3. Left: Photograph of distal surface of first premolar shown in Fig. 2. There is a 3.5 by 3.5 mm. loss of attachment below the cementoenamel junction *(CEJ),* and plaque has grown 2.5 mm. below gingival margin and 0.5 mm. below *CEJ.* **Right:** Mesial surface of same tooth. Between this surface and the distal surface of canine contact relationship had been fairly normal. *C.P.,* Contact point above papilla and supragingival plaque 2.6 mm. above *CEJ.*

attachment and (2) a downgrowth of subgingival plaque to the area of the cementoenamel junction.

The roentgenographs shown in Fig. 2 may give the clue to an understanding of the pathogenesis of the premature loss of attachment. Because of the lack of space, the crown of the erupting second premolar was, at an early stage, forced into direct contact with the roots of the first premolar and the first molar (Fig. 2, *left*), and this contact was maintained during the following 10 months (Fig. 2, *right*). The spatial relationship between the two premolars during this critical period is delineated in Fig. 4, *right*. It is quite obvious that the periodontal fibers must disappear in the area of direct contact between the two teeth. In the case shown in Fig. 3, *left,* however, the fibers were lost in an area 3.5 mm. wide. Furthermore, the attachment fibers were lost to a distance of 3.5 mm. below the deepest point of the subgingival plaque, and this is at least 2 mm. farther than subgingival plaque is known to cause loss of attachment under normal conditions.[4, 5] Therefore, the destruction of the collagen fibers must have been mediated by factors other than bacterial inflammation, and there is good reason to believe that it was caused by enzymes derived

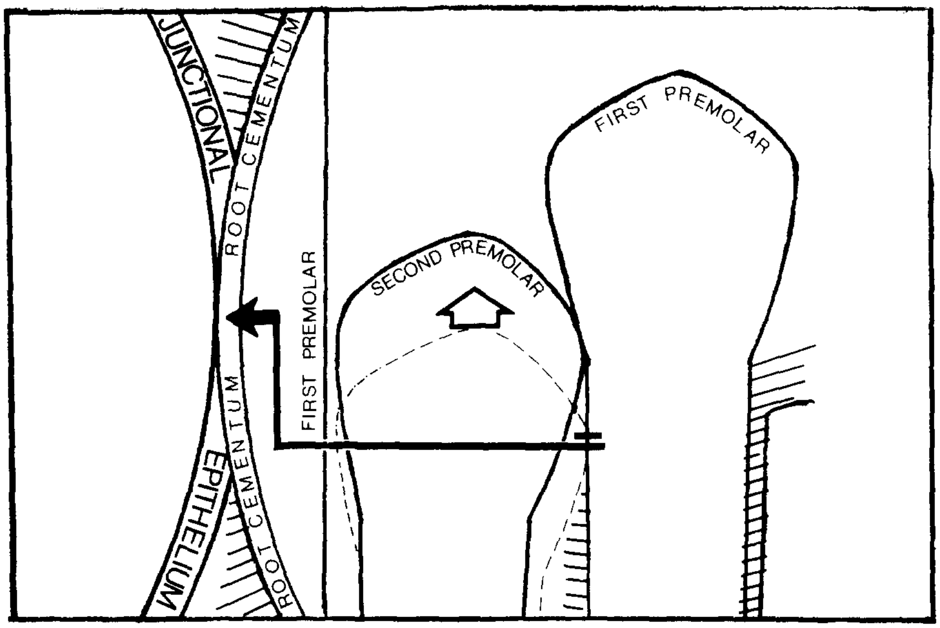

Fig. 4. Right: Schematic drawing to delineate contact relationship between crown of erupting second premolar and root of first premolar (Fig. 2, left and right) during interval when premature loss of attachment took place (Fig. 3). **Left:** Contact area seen in the horizontal plane to show how junctional epithelium surrounding erupting second premolar has come into contact with peridontal fibers of first premolar.

from the regressing dental organ or from the junctional epithelium surrounding the erupting second premolar as suggested in Fig. 4, *left*. Such an interpretation would be in agreement with basic research on the collagenase activity in gingival epithelium.[6-8]

The highly irregular contact relationship between the crowded teeth (Figs. 1 and 2) may give the clue to an understanding of the very rapid downgrowth of subgingival plaque. Thus, rather than a contact point above the tip of the papilla (Fig. 1, *left*), a more or less continuous contact line had been established with the papilla, splitting it in two (Fig. 1, *right*), and in this locus minoris resistentiae the antibacterial defense mechanism had been interfered with.

An enzyme-mediated loss of attachment alone would probably be of no clinical significance because it would be limited to the area of contact with the junctional epithelium. The real hazard to the longevity of the tooth is created by the presence of subgingival plaque in the area of the cementoenamel junction (Fig. 3, *left*) at a time when any plaque should be located supragingivally at a distance of 2.5 mm. or more above the same base line (Fig. 3, *right*). One major diagnostic problem is that subgingival plaque does not give visible symptoms of marginal gingivitis which can call the attention of the clinician to the unfavorable condition.[9] Therefore, the subgingival plaque is likely to remain undisturbed by scalers until it has advanced to the stage where it will continue the enzyme-mediated loss of attachment.

Thus, a combination of enzyme-mediated and plaque-mediated lysis of the periodontal fibers may have been responsible for the loss of attachment observed in 19- to 21-year-old

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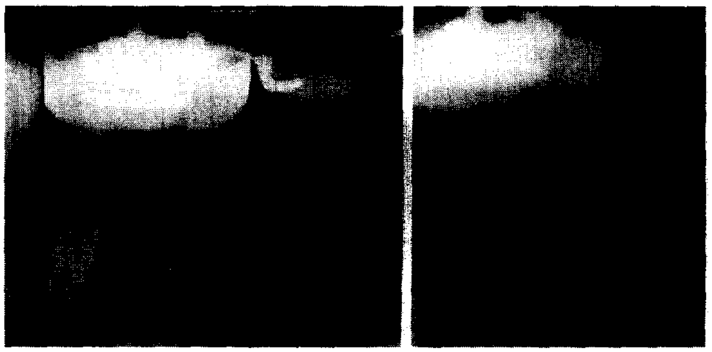

Fig. 5. Radiographs of second premolar and first molar 3½ months after extraction of first premolar shown in Figs. 2 to 4. Normal contact relationship has been attained by orthodontic treatment. Conditions on mesial surface of first molar during eruption had probably been similar to those on distal surface of first premolar (Fig. 3). Left radiograph shows angular bone defect facing mesial surface of first molar. Right radiograph shows probe inserted 4.5 mm. below cementoenamel junction, indicating loss of attachment of same magnitude as seen in Fig. 3. (Roentgenographs slightly retouched to bring out contrast in reproduction.)

men.[2] The same combination may also be partly responsible for the early bone resorption adjacent to lateral incisors and first molars in cases diagnosed as juvenile periodontitis.[5]

The observations made in the case shown in Fig. 5 may serve as guidelines for making an early diagnosis: (1) More than normal bleeding and pain on probing suggest the presence of subgingival plaque. (2) An angular bone defect facing a suspected tooth surface suggests loss of attachment (Fig. 5, *left*), and the suspicion may be verified by probing (Fig. 5, *right*).

If the subgingival plaque is diagnosed at an early stage, steps can be taken to have it eliminated before it has caused further damage.

Because the present material is highly selected, it does not allow any conclusions to be drawn regarding the prevalence of the conditions described in the population as a whole.

Conclusions

Because the eruption of teeth into a crowded environment predisposes to premature loss of attachment on the neighboring teeth as well as to downgrowth of subgingival plaque, which may cause even more damage in the future, there is a valid indication for eliminating the crowding by orthodontic means as an integral part of preventive periodontics. Due attention should be paid to the gingival and periodontal conditions around the teeth which already have erupted into a crowded position.

REFERENCES

1. Ingervall, B., Jacobsson, U., and Nyman, S.: A clinical study on the relationship between crowding of teeth, plaque and gingival condition, J. Clin. Periodontol. **4:** 214-222, 1977.
2. Ainamo, J.: Relationship between malalignment of teeth and periodontal disease, Scand. J. Dent. Res. **80:** 104-110, 1972.
3. Waerhaug, J.: A method for the evaluation of periodontal problems on extracted teeth, J. Clin. Periodonto. **2:** 160-168, 1975.

4. Waerhaug, J.: Subgingival plaque and loss of attachment in periodontosis as observed in autopsy material, J. Periodontol. **47:** 636-642, 1976.
5. Waerhaug, J.: Subgingival plaque and loss of attachment in periodontosis as observed on extracted teeth, J. Periodontol. **48:** 125-136, 1977.
6. Fullmer, H. M.: Collagenase and periodontal disease: A review, J. Dent. Res. **50:** 288-291, 1971.
7. Fullmer, H. M., Gibson, W. A., and Lazarus, G. S.: The origin of collagenase in periodontal tissues in man, J. Dent. Res. **48:** 646-651, 1969.
8. Taylor, A. C.: Collagenolysis in cultured tissue: Digestion of mesenteric fibers by enzymes from explanted gingival tissue, J. Dent. Res. **50:** 1294-1330, 1971.
9. Waerhaug, J.: The furcation problem: Etiology, pathogenesis, diagnosis, therapy, and prognosis.

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The relationship between irregularity of the incisor teeth, plaque, and gingivitis: a study in a group of schoolchildren aged 11–14 years

F. P. Ashley*, L. A. Usiskin*,†, R. F. Wilson* and E. Wagaiyu**
*United Medical and Dental Schools of Guy's and St Thomas' Hospitals, London, UK and
**Dental School, University of Nairobi, Kenya

SUMMARY The relationship between irregularity of teeth and periodontal disease was investigated in 201 children aged 11–14 years. The upper and lower incisor teeth were assessed for spacing, labio-lingual displacement, and mesiodistal overlap at each of the six contact areas. Plaque and gingivitis were assessed at six sites on each of the four upper and four lower incisor teeth. There was evidence for a direct relationship between the number of contact areas with tooth displacement combined with overlap and the number of sites with gingival redness ($R = 0.25$, $P < 0.001$), bleeding ($R = 0.18$, $P < 0.01$), and profuse bleeding ($R = 0.25$, $P < 0.001$). There was no evidence for a relationship between labio-lingual displacement alone and gingivitis. One-hundred-and-twenty-eight subjects without tooth displacement combined with incisor overlap had, respectively, 34, 15, and 35 per cent fewer sites with redness ($P < 0.01$), bleeding ($P < 0.05$), or profuse bleeding ($P < 0.01$) than the 73 subjects with overlap. The statistical significance of these differences was unaffected by covariate adjustment to take account of the effect on gingivitis of variation in the number of sites with plaque. There was no evidence of a relationship between incisor overlap and amount of plaque in these subjects. The results indicate that overlapping of incisor teeth is directly related to gingivitis and this relationship cannot be explained simply by an effect on oral hygiene.

Introduction

One possible justification for orthodontic treatment is that irregular teeth are more difficult to clean and therefore predisposed to gingivitis. However, when considering the possible risks and benefits of orthodontic treatment, Shaw *et al.* (1991) drew attention to the contradiction in research findings concerning the relationship between dental irregularity and periodontal disease. They considered that this arose from the difficulty of distinguishing the effect of irregularity from that of other important factors such as social class, gender, motivation and even toothbrushing hand (Addy *et al.*, 1988). The main influence of these factors on gingivitis would be through differences in the effectiveness of oral hygiene procedures. This view finds general support in the literature, for example, Buckley (1981) found that individual tooth irregularity had a low, but statistically significant correlation with plaque and gingival inflammation in a group of 300 teenagers, although he considered that the likely sequence was that crowded and irregular teeth facilitated the accumulation of bacterial plaque and then indirectly contributed to gingival inflammation.

Ainamo (1972), in a study of 154 army recruits, noted that periodontal disease was worse when adjacent to malaligned teeth around the maxillary anterior teeth, but the relationship was less marked in the premolar areas. He considered that an association between malalignment of teeth and periodontal disease would be most evident

†Deceased.

in the presence of average rather than exceptionally good oral hygiene or no oral hygiene. Presuming that the degree of malalignment allowed 'exceptionally good oral hygiene', then clearly such a level of plaque control would be consistent with periodontal health. However, it is possible to envisage malalignment, specifically that resulting in approximated roots, which would render it extremely difficult if not impossible to attain such a high standard of plaque control.

In a study of 11–14-year-old children a relationship between both mouth-breathing and lip coverage of the upper incisor teeth and gingivitis has been demonstrated (Wagaiyu and Ashley, 1991). Data on incisor irregularity were also collected, but the initial analysis of these data was extremely limited. The aim of the present study was to carry out a more detailed analysis of the data relating to incisor irregularity and gingivitis, and to investigate the influence on this relationship of other factors such as plaque amount and both mouth-breathing and lip coverage of the upper incisor teeth.

Subjects and methods

The subjects were 201 schoolchildren from the first three years of an inner-city comprehensive school. Parental consent had been obtained for 213 subjects to be examined; five subjects were absent from school and seven were excluded because of the presence of orthodontic appliances. The group comprised 86 females and 115 males with a mean age of 12.7 years (SD = 0.9).

Each subject was assessed by two examiners. The first examiner (EW) recorded gingivitis and irregularity, and the second (FPA) assessed plaque accumulation, as well as mouth-breathing and lip coverage of the upper incisor teeth. The mesio-buccal, mid-buccal, and disto-buccal sites together with the corresponding palatal sites on each of the eight upper and lower incisor teeth were assessed in each subject, yielding 48 sites per subject. The gingival assessment included the recording of the presence or absence of gingival redness and bleeding on probing (Sidi and Ashley, 1984). Plaque accumulation was assessed initially using modified Silness and Löe (1964) criteria where code 2 (plaque visible without probing) was the maximum score used. Subsequently, all the available plaque was collected from these sites and dry weight estimated (Ashley *et al.*, 1984). Irregularity was assessed for the three contact areas of the incisor teeth in each jaw by recording the amount (mm) of spacing, mesiodistal overlap, and labio-lingual displacement for each of the contact areas using a metal ruler (Todd and Lader, 1988). Spacing, displacement, or overlap of less than 1 mm was not recorded. Upper lip coverage of the maxillary incisors was categorized using the criteria of Addy *et al.* (1987).

An assessment of whether the subjects were predominantly mouth-breathers was made on the basis of both observation, their response to questioning, and by the use of a mirror test (Wagaiyu and Ashley, 1991). The test was carried out by placing a double-sided mirror in a horizontal position between mouth and nose, and asking the subject to breathe normally whilst seated in a relaxed upright position.

In the statistical analysis clinical variables such as plaque and bleeding on probing, which had been recorded at two levels of severity, were collapsed to create dichotomous scores and the number of sites per subject which were affected was calculated.

The status of the six contact areas of the upper and lower incisor teeth was expressed as the number of contact areas with labio-lingual displacement with mesiodistal overlap, labio-lingual displacement without mesiodistal overlap, either type of configuration (a combination of the last two variables), and finally spacing.

Initially, the relationship between clinical variables was assessed using Spearman correlation coefficients, as it was difficult to achieve a normal distribution with variables representing irregularity of teeth. Subsequently, analysis of variance was performed comparing subjects with and without mesiodistal overlap for gingivitis using plaque, mouth-breathing, and lip coverage as covariates. Subjects were also split into three groups of approximately equal size according to their oral hygiene status in order to permit examination of the relationship between incisor irregularity and gingivitis in subjects with good, moderate, or poor oral hygiene. Finally, limited

Table 1 Mean scores for irregularity and spacing of incisor teeth: six contact areas assessed (201 subjects).

	Mean	Standard deviation
Contact areas with:		
Labio-lingual displacement with mesiodistal overlap	0.64	1.07
Labio-lingual displacement without mesiodistal overlap or spacing	0.30	0.66
Overlap and/or displacement without spacing	0.94	1.27
Spacing	0.80	1.23

Table 2 Mean scores for plaque and gingivitis around incisor teeth: 48 sites assessed (201 subjects).

	Mean	Standard deviation
Number of sites with:		
Plaque	20.14	11.71
Visible plaque	4.08	6.69
Plaque dry weight (mg)	1.63	1.61
Number of gingival sites with:		
Redness	10.32	10.52
Bleeding on probing	23.58	11.23
Profuse bleeding on probing	9.06	9.28

Table 3 Spearman correlation coefficients: number of contact areas with irregularity or spacing versus gingivitis scores (201 subjects).

	Number of gingival sites with		
	Redness	Bleeding	Profuse bleeding
Number of contact areas with:			
Labio-lingual displacement with mesiodistal overlap	0.25***	0.18**	0.25***
Labio-lingual displacement without mesiodistal overlap or spacing	0.04	−0.01	−0.06
Overlap and/or displacement without spacing	0.22**	0.15*	0.19**
Spacing	−0.10	−0.23***	−0.22**

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

analysis was carried out for the upper and lower incisor sites separately. Examiner reproducibility was assessed by repeating the examination of 16 randomly selected subjects after the completion of the main study.

Results

Seventy-three of the 201 subjects had one or more incisor teeth contact areas with labio-lingual displacement and mesiodistal overlap, 41 had displacement without overlap or spacing, 97 had overlap and/or displacement without spacing, and 77 had spacing. The mean values for irregularity and spacing are presented in Table 1, and for plaque and gingivitis in Table 2.

The pattern of correlation observed between irregularity and gingivitis (Table 3) indicated a consistent, statistically significant, direct relationship between the number of sites with labio-lingual displacement combined with mesiodistal overlap and gingivitis, but there was no evidence for a relationship between labio-lingual displacement and gingivitis if mesiodistal overlap was absent. There was still evidence of a statistically significant direct relationship between the number of sites with irregularity of any kind and gingivitis, but the level of statistical significance was reduced in comparison with consideration of sites with labio-lingual displacement combined with mesiodistal overlap. There was a statistically significant inverse relationship between the number of sites with spacing and the number of sites with bleeding ($0.01 > P > 0.001$), but not with the number of sites with gingival redness.

As expected, the three measures of plaque showed statistically significant positive correlations with gingivitis (Table 4), but there was no

Table 4 Spearman correlation coefficients for all incisor sites: plaque versus gingivitis and plaque versus crowding or spacing (201 subjects).

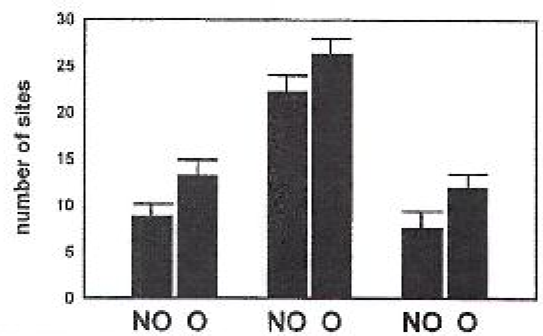
	Number of sites with Plaque	Visible plaque	Plaque dry weight
Number of gingival sites with:			
Redness	0.58***	0.52***	0.52***
Bleeding on probing	0.39***	0.32***	0.34***
Profuse bleeding on probing	0.41***	0.38***	0.37***
Number of contact areas with:			
Labio-lingual displacement with mesiodistal overlap	0.08	0.03	0.07
Labio-lingual displacement without mesiodistal overlap or spacing	–0.08	–0.10	–0.08
Overlap and/or displacement without spacing	0.05	–0.01	–0.03
Spacing	–0.02	0.13	0.05

***$P < 0.001$.

evidence in these subjects of any relationship between irregularity and plaque. Notwithstanding, it was considered important to determine whether variations in gingivitis due to plaque were contributing to the relationship observed between labio-lingual displacement combined with mesiodistal overlap and gingivitis.

The 128 subjects without displacement combined with overlap of incisor teeth had respectively, 34, 15, and 35 per cent fewer sites with redness, bleeding, or profuse bleeding than the 73 subjects with both displacement and overlap of one or more incisor teeth (Figure 1). The statistical significance of these differences was unaffected by covariate adjustment to take account of any influence of variation in the number of sites with plaque or gingivitis. Further covariate adjustment to take account of additional variation due to mouth-breathing and lip coverage was also carried out resulting in F values of 5.41 ($P = 0.02$) for sites with redness, 2.19 ($P = 0.14$) for sites with bleeding, and 4.53 ($P = 0.04$) for sites with profuse bleeding.

The subjects were then split into three groups of approximately equal size according to their oral hygiene status (Table 5). A trend to an increase in the number of sites with displacement combined with overlap was noted as the groups' plaque scores increased, but there were no statistically significant differences between these



	redness	bleeding	profuse bleeding
ANOVA	8.95**	5.56*	9.60**
COVA adjusted for plaque	8.73**	4.58*	8.79**
COVA adjusted for plaque, lip coverage and mouthbreathing	5.41*	2.19	4.53*

* p<0.05 ** p<0.01

Figure 1 Bar diagram showing mean number of sites with redness, bleeding, or profuse bleeding for 128 subjects without labio-lingual displacement combined with mesiodistal overlap (no incisor overlap, NO) and 73 subjects with this condition (incisor overlap, O) at one or more incisor contacts. Bars represent standard errors of the mean. Table shows variance ratios (F values) for the differences between groups by analysis of variance (ANOVA) and analysis with covariate adjustment (COVA).

Table 5 Mean scores (SD) for displacement with overlap and gingivitis in subjects categorized according to plaque amount: group 1: 0–12 sites with plaque (n = 64); group 2: 13–26 sites (n = 69); group 3: >26 sites (n = 68).

	Group 1	Group 2	Group 3	P value*
Number of contact areas with displacement combined with overlap	0.48 (0.98)	0.67 (1.01)	0.75 (1.21)	0.35
Number of gingival sites with:				
Redness	3.77 (6.71)	9.48 (8.67)	17.35 (10.94)	<0.001
Bleeding on probing	19.03 (9.76)	23.04 (10.68)	28.41 (11.29)	<0.001
Profuse bleeding on probing	5.25 (5.64)	7.93 (8.65)	13.78 (10.67)	<0.001

*P-value related to overall analysis of variance between groups.

Table 6 Spearman correlation coefficients: irregularity versus gingivitis according to oral hygiene group: group 1: 0–12 sites with plaque (n = 64); group 2: 13–26 sites (n = 69); group 3: >26 sites (n = 68).

	Group 1 Good OH	Group 2 Moderate OH	Group 3 Poor OH
Number of contact areas with displacement combined with overlap versus number of gingival sites with:			
Redness	0.18	0.26*	0.26*
Bleeding on probing	0.06	0.12	0.31**
Profuse bleeding on probing	0.15	0.25*	0.31**

*$P < 0.05$; **$P < 0.01$.

Table 7 Spearman correlation coefficients: upper and lower incisors sites with displacement combined with overlap versus gingivitis scores (201 subjects).

Labio-lingual displacement with mesiodistal overlap:	Redness	Bleeding	Profuse bleeding
Upper incisors	0.17*	0.20**	0.21**
Lower incisors	0.19*	0.09	0.22**

*$P < 0.05$; **$P < 0.01$.

groups. Not surprisingly there were large, statistically significant differences in gingivitis between these groups.

A statistically significant relationship was observed between the number of sites with displacement combined with overlap and gingivitis in the moderate and poor oral hygiene groups, especially the latter (Table 6).

There was no evidence of a relationship in the subjects categorized as having good oral hygiene.

Finally, the data for the upper and lower incisor teeth were analysed separately (Table 7). The pattern of correlation observed was similar to that seen for upper and lower incisors combined (Table 3).

Reproducibility assessment based on the re-examination of 16 subjects approximately 3 months later indicated good agreement for both the number of sites with displacement and overlap, and sites with displacement alone, Cohen's Kappa being 0.7 (Bulman and Osborn, 1989). Reproducibility data for the other measurements have been published (Wagaiyu and Ashley, 1991).

Discussion

The results of the present study support the concept that there is an association between the presence of irregular incisor teeth and gingivitis. This relationship was more evident for incisor irregularity manifested by labio-lingual displacement with overlap rather than labio-lingual displacement without overlap. It is likely that the combination of displacement and overlap would have a more adverse effect on the ability to clean the approximal tooth surfaces than labio-lingual displacement alone and this might explain this finding. Such an explanation would also be consistent with the finding that spacing was associated with better gingival health in these 11–14-year-old schoolchildren. It is interesting to note that there is no evidence of a similar relationship in adults (Jernberg *et al.*, 1983; Årtun and Osterberg, 1987)

Association does not infer causation and it might be argued that the presence of irregular teeth in 11–14-year-old subjects when orthodontic care is available could be indicative of a low level of dental awareness, which in turn might be accompanied by a less enthusiastic approach to oral hygiene. This did not appear to be the case in the present study as no relationship was found between irregularity and either the number of sites with plaque or the dry weight of the plaque which was collected from the incisor teeth. This finding contrasts with that of some earlier studies (for example, Alexander and Tipnis, 1970; Buckley, 1981; Griffiths and Addy, 1981), where statistically significant correlations were noted between crowding and amounts of plaque.

This discrepancy may relate to the different methods used in the present study to assess irregularity and plaque, and to the fact that the investigation was limited to the incisor teeth. Nevertheless, both irregularity and plaque correlated separately with gingivitis. The only evidence in the present study for an effect of irregularity on plaque accumulation came from the categorization of subjects into three groups according to oral hygiene status (Table 5) when a trend for incisor overlap to be least prevalent in subjects with the lowest plaque scores was noted.

If the relationship between irregularity and gingivitis is not secondary to a relationship between irregularity and plaque another explanation is required. One possibility is that incisor overlap has an effect on the shape and size of the gingival tissues, in particular their thickness. Waerhaeg (1979) put forward the concept of a limited zone of destruction in the gingival connective tissue in relation to adjacent plaque deposits. It is possible that when overlapped teeth result in a very 'thin' gingival tissue, especially interdentally, plaque deposits on one tooth surface may result in gingival inflammation at more of the adjacent sites than would have been the case if no overlapping was present and the gingival tissues were 'thicker'. It should also be remembered that such irregularity may result in an increase in the area of plaque on the approximal surfaces which would not only be inaccessible to tooth brushing, but also to assessment, using the methods employed in the present study. In addition, variations in the composition of plaque rather than the amount of plaque may also have contributed to the present findings.

The results do not suggest that incisor overlap is associated with gingivitis in the absence of plaque as there was no evidence of statistically significant relationships between irregularity and gingivitis in the subjects who were categorized as having good oral hygiene. However, there was a relationship between irregularity and gingivitis not only, as expected, in subjects with moderate oral hygiene, but also in subjects with poor oral hygiene (Table 6). This appears to contradict Ainamo's (1972) suggestion that when oral hygiene was poor or non-existent, an association between malalignment and gingivitis would be less likely to be revealed. However, in the poor oral hygiene group (Table 5, Group 3) there was considerable variation in the number of sites with gingivitis, whereas Ainamo found that in his subjects the plaque and gingivitis scores approached maximum values around the posterior teeth in all subjects, reducing the possibility of finding differences associated with malalignment. It is interesting to note that Behlfelt *et al.* (1981) who compared normal and malaligned teeth within the same subjects found that plaque and gingivitis were more widespread around malaligned upper lateral incisors and lower second premolars than around contralateral teeth well positioned within the dental arches. They considered that their subjects were of 'average' oral hygiene.

Mouth-breathing and lip coverage of the upper incisor teeth are two factors which have been shown to be associated with gingivitis in the present subjects, in particular at sites around the incisor teeth (Wagaiyu and Ashley, 1991). Analysis of the data using these factors as covariates reduced, but did not eliminate, the statistical significance of the mean differences seen in gingivitis between subjects with and without overlap of incisor teeth. It is recognized that assessment of mouth-breathing is difficult. However, the examiner in the present study had routinely assessed mouth-breathing clinically for over 30 years.

The reduction in statistical significance seen as a result of using mouth-breathing and lip coverage as covariates is consistent with the earlier finding of Jacobson and Linder-Aronson (1972) who reported that there was a correlation between crowding and gingivitis in 55 children who were mouth-breathers which was not apparent in 40 children who were nose breathers.

It should be stressed that the present study was not concerned with periodontitis and in view of the known variation in susceptibility to periodontitis in subjects with gingivitis (Löe *et al.*, 1986) it would be difficult to establish whether the relationship observed between incisor irregularity and gingivitis would be translated to a relationship with periodontitis in adult life. The question arises: is it reasonable to use the present results to support the case for orthodontic treatment to improve periodontal health in the absence of such information? Incisor irregularity was not associated with significant gingival inflammation in the subjects with good oral hygiene, but for many subjects it is difficult to achieve consistently good oral hygiene in the long-term for a variety of reasons. These results suggest that most patients would have less gingival inflammation if they did not have overlapped incisors. In addition, the fact that part of the relationship between incisor crowding and gingivitis appeared to be independent of variations attributable to our assessment of plaque, mouth-breathing, or lip coverage, suggests that further work on the exact mechanisms underlying the relationship of crowding and gingivitis is required.

Address for correspondence

Professor F. P. Ashley
United Medical & Dental Schools
Floor 21, Guy's Tower,
Guy's Hospital
London SE1 9RT, UK

References

Addy M, Dummer P M H, Hunter M L, Kingdom A, Shaw W C 1987 A study of the association of fraenal attachment, lip coverage and vestibular depth with plaque and gingivitis. Journal of Periodontology 58: 752–757

Addy M *et al.* 1988 The association between tooth regularity and plaque accumulation, gingivitis and caries in 11–12 year old children. European Journal of Orthodontics 10: 76–83.

Årtun J, Osterberg S K 1987 Periodontal status of teeth facing extraction sites long-term after orthodontic treatment. Journal of Periodontology 58: 24–29

Ainamo J 1972 Relationship between malalignment of the teeth and periodontal disease. Scandinavian Journal of Dental Reseach 80: 104–110

Alexander A G, Tipnis A K 1970 The effect of irregularity of teeth and the degree of overbite and overjet on gingival health. British Dental Journal 128: 539–544

Ashley F P, Skinner A, Jackson P Y, Wilson R F 1984 Effect of a 0.1 per cent cetylpyridinium chloride mouthrinse on the accumulation and biochemical composition of dental plaque. Caries Research 18: 465–471

Behlfelt K, Ericsson L, Jacobson L, Linder-Aronson S 1981 The occurrence of plaque and gingivitis and its relationship to tooth alignment within the dental arches. Journal of Clinical Periodontology 8: 329–337

Buckley L A 1981 The relationship between malocclusion, gingival inflammation, plaque and calculus. Journal of Periodontology 52: 35–40

Bulman J S, Osborn J F 1989 Measuring diagnostic consistency. British Dental Journal 166: 377–381

Griffiths G S, Addy M 1981 Effects of malalignment of teeth in the anterior segments on plaque accumulation. Journal of Clinical Periodontology 8: 481–490

Jacobson L, Linder-Aronson S 1972 Crowding and gingivitis: a comparison between mouthbreathers and nosebreathers. Scandinavian Journal of Dental Research 80: 500–504

Jernberg G R, Bakdash M B, Keenan K M 1983 Relationship between proximal tooth open contacts and periodontal disease. Journal of Periodontology 54: 529–533

Löe H, Anerud A, Boysen H, Morrison E 1986 The natural history of periodontal disease in man. Rapid, moderate and no loss of attachment in Sri Lankan labourers 14–46 years of age. Journal of Clinical Periodontology 13: 431–440

Shaw W C, O'Brien K D, Richmond S, Brook P 1991 Quality control in orthodontics: risk/benefit considerations. British Dental Journal 170: 33–37

Sidi A D, Ashley F P 1984 Influence of frequent sugar intakes on experimental gingivitis. Journal of Periodontology 55: 419–423

Silness J, Löe H 1964 Periodontal disease in pregnancy (II). correlation between oral hygiene and periodontal condition. Acta Odontologica Scandinavica 22: 121–135

Todd J E, Lader D 1988 Adult dental health, United Kingdom Office of Population Censuses and Surveys, Social Survey Division, P336, HMSO, London

Waerhaug J 1979 The angular bone defect and its relationship to trauma from occlusion and downgrowth of subgingival plaque. Journal of Clinical Periodontology 6: 61–82

Wagaiyu E G, Ashley F P 1991 Mouthbreathing, lipseal and upper lip coverage and their relationship with gingival inflammation in 11–14 year old schoolchildren. Journal of Clinical Periodontology 18: 698–702

ADULT ORTHODONTICS

MARVIN C. GOLDSTEIN, D.D.S., ATLANTA, GA.

THE past fifty years have been perhaps the most unusual ones in our history. During that time scientists throughout the world have made vast strides in every field of endeavor, culminating in our current age of atomic energy.

Along with this "scientific revolution" has come an expected change in the pattern of man's thinking. With new-found economies, more people have been able to go to colleges and universities than ever before, and, as a result, more profound thought, and more people desiring the best in life, have been and are being produced.

Dentistry, keeping pace with all other branches of science and medicine, has grown rapidly during the past few years. With the advancement of dentistry to its present high plane, more demand has been created for orthodontic service for the adult. Now, more than ever before, the adult with varying degrees of dentofacial deformities presents himself to the dentist and earnestly desires to be helped. Now, also more than ever before, the general practitioner of dentistry is calling on the orthodontist for help in the proper treatment of these deformities. The general dentist is the man responsible for the dental health of the patient, and the progressive practitioner is constantly studying and using all available facilities for the best interest of his patient.

It appears that orthodontic treatment for adults has received comparatively little space in the literature in recent years, and, as a result, attention given it has been virtually negligible. Because of this lack of interest in so important a phase of the orthodontic field, many dentists have come to feel that orthodontics is not recommended for adults, and, sad to relate, many orthodontists have shared this feeling. In a poll taken by the Pierre Fauchard Academy[1] in 1947, it was revealed that 49 per cent of the dentists practicing some orthodontics do not treat any adults. This would indicate, then, that a great many adults must go through life with deformities that could have been corrected.

Adults can and should be treated, and it is the purpose of this article to set out several lines of procedure for adult therapy and to show various types of conditions amenable to treatment, along with the prescribed treatment.

REVIEW OF THE LITERATURE

The orthodontic treatment of adults is by no means a recent idea. Pierre Fauchard, author of the first known scientific book on dentistry, *Le Chirurgien*

This thesis, which was given as a partial fulfillment of the requirements for certification by the American Board of Orthodontics, is being published with the consent and the recommendation of the Board, but it should be understood it does not necessarily represent nor express the opinion of the Board.

Dentiste, written in 1723, was probably the first to discuss adult treatment by his observation that the teeth of young people are easier to straighten than those of older persons.[2] He further said, "When persons of years undertake to have this performed, considerable time is required before success can be obtained."

In 1768, Thomas Berdmore in his book, *A Treatise on the Disorders and Deformities of Teeth,* discussed adult treatment and indicated it should not be attempted.[2] For the next hundred years or so, the literature reveals that this was the prevailing view. The first great change in this trend seemed to come in 1858 when Henry Peebles, in the *American Dental Review* said, ". . . I deem all cases of irregularity . . . remediable or curable. I prefer taking charge of such cases, as a general rule, at a period of age above, rather than below 25 years of age. I then have a mature mental and moral as well as a mature physical subject to deal with."[2] In my study of the literature, this seems to be the first statement of a preference for adult treatment, and it probably did much to influence more adult therapy in the years following.

In 1880, Kingsley,[3] in discussing treatment age, said, "It may be regarded as a settled fact that there is hardly any limit to the age when the movement of teeth might not succeed. Such success must depend on favoring circumstances. It is a common occurrence at all ages, but particularly with people of advanced age, to see teeth changing and assuming new positions, as the result of the loss of adjoining or occluding teeth. . . . The occlusion of the teeth is a most potent factor in determining the stability in a new position. If the occlusion will be such as to favor the retention of moved teeth in their new position, then considerable movement may be attempted at almost any age at which it might be desired and with an expectation of success. The older the patient and the larger the number of teeth to be moved, the longer time must they be held by some means external to themselves . . . even to two or three years." Dr. Kingsley further gives a case report of simple movement in a woman aged 35 years.

Victor Hugo Jackson[4] was one of the early pioneers of our specialty, and in 1904 stated in his book, "In determining whether to correct the position of teeth for adult patients, the age is not so much to be taken into consideration as is the permanent advantages to be gained by the operation—namely, the improved occlusion and appearance of the teeth, the prevention of excessive wear on them and the contour of the features. In case of older patients the health and firmness of the teeth in their sockets must be considered. I have been successful in the correction of many cases of irregularity in patients from 40 to 50 years of age." Here, for the first time, a claim was made for successful treatment of many patients at advanced ages.

Guilford[5] in 1905, along the same vein, said, "Patients may present for treatment at almost any age. Under favoring conditions the operation may be begun and carried forward successfully through a wide range of years, the author having succeeded in one case as late as the forty-fifth year."

Since 1900, when orthodontics became a specialty with Dr. Angle devoting his practice exclusively to it, the literature shows scattered articles regarding adult orthodontic therapy. In *Practical Orthodontia,*[6] Kelsey discusses treatment of an adult suffering from Class III malocclusion. He also has a short paragraph on malocclusion developing in an adult in which he indicates treatment should be approached with extreme caution.

Jack Salzmann[7] devotes a page in his book to orthodontic treatment of adults, and much of it bears repeating. "Such treatment," Dr. Salzmann says, "is possible when performed in accordance with natural functional forces and with due consideration to the biochemical differences of bone as found in the child and in the adult. Bone growth and phosphatase activity are in a more passive state in the adult than in the child. Rapid growth of bone does not take place in the adult and osteoclastic activity due to orthodontic tooth movement may exceed osteoblastic activity diminishing the thickness of the labial and buccal alveolar plates when expansion of dental arches is accomplished too rapidly. Movement of shifted posterior teeth in a mesial or distal direction may be successfully accomplished in adults. Individual tooth movement in labial or lingual direction by means of mechanical appliances may be performed with less danger of relapse, provided this change in position of the teeth brings them in a more favorable position as far as function is concerned.

"After individual tooth movement has been effected, arch expansion may be undertaken. Orthodontic treatment in the adult is thus the reverse of that in the child where arch relating is usually undertaken before positioning of individual teeth."

A review of still further available literature[8-14] shows articles in the various dental journals on adult corrections, but, for the most part, these give individual case reports with little said regarding means, methods, and considerations. Thus, there seems to be a need for an analysis of adult malocclusion correction, its indications, contraindications, preferred treatment procedures, and danger points.

STUDY OF STRUCTURES

The dictionary defines an adult as "one who or that which has attained the age of maturity or legal majority." In applying this definition to our patients for orthodontic correction, we might say that adult orthodontics is that phase of orthodontics devoted to persons having completed most of their growth, usually 18 years of age or over. Therefore, when we think of adult therapy, we must think along different lines than for children because we must assume that growth and development are complete and can no longer be of aid in our treatment. We must consider the limitations of the structures present at the time treatment is being considered and know that although we can change the alveolar structure, we will be unable to secure any additional true bony structure. We have no control over the skeletal pattern, but we can exert some control over the denture area.

The history of the supporting structures and the tissue response to orthodontic therapy has been well covered in the literature.[15-18] Oppenheim[16] once stated that mature bone should respond just as well as younger bone, but his later research brought forth a confession that he was wrong. His work indicated that a longer time is required before mature bone is attacked by osteoclasts than is required in young bone. Correct diagnosis before treatment is started is essential because there will be far less damage to the tissues if the direction of movement, once started, is not changed.

Orthodontic treatment is based on the known phenomena of bone apposition and bone resorption which are continuous processes throughout life. It would seem, therefore, that there is no reason for age limitations per se.

The available evidence indicates that care must be taken that excessive force is not placed on the teeth. Especially in adults, extensive destruction of the periodontal tissues, as well as of the tooth root, may be caused by too severe tooth movement. Proper mechanics and mass movement of teeth can be accomplished without using too strong a force and thus cause little destruction of the supporting tissues.

According to Stuteville[18] the periodontal membrane and pulp may be injured during tooth movement, but they have the ability to repair and usually do so. Whereas it has been indicated by some that banding appliances cause more root resorption, Stuteville makes the statement that "the more stable appliances cause fewer root resorptions than auxiliary springs." He feels that more injury is produced by interfering forces of occlusion than by appliance force.

AGE FACTOR

The question of an age limit for orthodontic correction is frequently a subject of discussion. Based upon what we have already seen, it seems that if the need for a correction is present, the patient is desirous of such treatment, and the clinical and x-ray studies show the bone and other supporting structures to be healthy, then the age factor can be minimized. Dr. George Moore,[19] professor of orthodontics at the University of Michigan, observed, "In healthy individuals as old as 35 or 40 quite comprehensive programs of orthodontic treatment involving extensive tooth movement are being handled every day with great success and patients up to 25 are showing uniformly good results with apparently little hazard to the teeth and supporting structure." In discussing the age factor it might be of interest to quote some of our leading orthodontists of twenty-five years ago, most of whom, I am happy to say, are still with us and still qualify in that role.

Although these statements were made in 1927 in answer to a questionnaire sent out by Dr. Frank Gray,[20] I feel that they are just as apropos today and show the opinions of some of the truly great men in our field:

Dr. Alfred P. Rogers.—"Recent years have proved that proper methods may be used with great effect on adults. In my own experience, very satisfactory results were obtained in a patient 40 years of age resulting in better occlusion and health of the mouth."

Dr. James D. McCoy.—"It is difficult to state an age limit but it seems to me that after a patient has reached 30, tooth movement unless very limited should not be attempted."

Dr. Harold Chapman.—"I would not undertake treatment of a case at age 16 or later unless for a specific reason."

Dr. C. A. Hawley.—"I have treated a number of patients at 35-40."

Dr. Joe Eby.—"I have an aversion to adult work and never attempt it unless the preventive aspect of impending functional disaster renders the situation imperative."

Dr. Allen H. Suggett.—"I have made very extensive movements of the teeth in patients 30-40. I am bringing down to position an impacted cuspid for a woman over 50. The reaction is no different from the ordinary."

Dr. Leuman Waugh.—"Individual tooth movement, i.e., to facilitate proper restorations, etc., may be undertaken up to 50 years. For reshaping of arches seldom beyond 30 years."

Dr. Lischer.—"In adult life treatments should only be undertaken if the oral health of the individual is good and full cooperation assured."

Dr. Mershon.—"I treat a good many adults, meaning past 18, with very gratifying results."

Dr. Ketcham.—"No arbitrary limit if patient may be benefitted."

It can thus be seen that although some differences of opinion have existed regarding treatment of adults, there is almost general unanimity as to the need for such treatment and its place in our specialty.

The aging dentition, of course, must be taken into consideration, and it must be decided that changing the position of the teeth and jaws will be of sufficient reward to the patient to warrant the treatment. Thus, it would be well to discuss briefly some of the indications for adult therapy.

INDICATIONS FOR ADULT THERAPY

Individual Normal Occlusion.—In discussing indications for adult treatment, it is necessary to determine what is normal occlusion. The various definitions of a normal occlusion cannot be accepted as laws, but only as starting points from which deviations can take place and still be well within individual normal range.

According to A. Leroy Johnson,[21] an individual normal occlusion may be defined as "one which differs from all other normal occlusions to some extent but still satisfies all of the requirements of a normal occlusion."

Lowrie J. Porter,[22] in discussing the subject, says, "We must remember that the average normal is not the individual normal and that an individual normal which has been established by muscular pressure may appear to be an abnormality when judged by the average normal standard."

God has given differences to us all, and it is evident that there can be no set pattern for a normal. Many people go through life short or tall, small or large, pretty or homely, all individual normals, perhaps. Heredity has played its part in deciding these characteristics and, also, heredity has played its part with jaw and teeth formation.

According to Ernest L. Johnson,[23] "Facial patterns are of utmost importance in orthodontic prognosis and treatment. There would appear to be little doubt that facial patterns are determined by heredity in large part, or by other deep-seated factors not susceptible to modification. There may be a great deviation in the individual pattern from the so-called normal or ideal type of pattern. Yet these extremes are in one sense normal for that individual and many of the individual deviations from the acceptable pattern are not within the realm of orthodontic corrections."

We must decide what is a pathologic condition and what is within the range of a normal occlusion. Is every person who has a mild malocclusion, as judged by Angle's classification, or others, to be told treatment is necessary? Is it not probable that many of these cases may be normal for the particular individual? We see many adults, 50, 60, even 70 and over, with these types of so-called malocclusion, and still the teeth and tissues are all in good condition and the facial lines pleasant and of no concern. One can be quite capable of good masticatory ability and function with the tissues healthy and still the occlusion may be far from perfect. We must determine the limits between the normal and the abnormal for the particular individual being studied.

Pretreatment Considerations.—Some of the indications for adult treatment are:

1. Facial deformities
   a. Protrusions of upper anterior teeth and/or with protrusion of complete upper arch
   b. Protrusion of lower jaw
   c. Severe lateral cross-bite
   d. Close-bite causing excessive grinding of teeth and loss of vertical dimension.
2. Malfunction of the teeth
   a. Individual tooth cross-bite
   b. Spacing of teeth due to extraction, missing teeth, or impactions
   c. Severe crowding causing periodontoclasia
   d. Traumatic occlusion
   e. Mutilations due to neglect
   f. Irregularity causing food packs and caries
3. Denture deformities without pathologic sequelae
4. Psychosomatic consideration
5. Pain
   a. Mandibular displacements
   b. Temporomandibular joint disturbance

We must feel certain that we are rendering a real service in treatment, because treating an adult presents certain problems not usually encountered in the younger patients. One of the major problems is the irritability of the adult to mouth appliances. Whereas a younger patient can become accustomed to appliances quickly, in an adult the irritability threshold is lower and at times he may become discouraged or irritated to the point of asking for appliance removal. It, therefore, becomes important to prepare the adult properly before treatment is started, explaining what he can expect (and certainly not minimizing the discomfort). If it is emphasized before appliances are placed that there will be some soreness of the teeth and a certain amount of discomfort, but that the final result will be well worth the period of discomfort, the orthodontist can save himself from many disagreeable talks with the patient at a later date. Usually the patient will indicate that the treatment was not as bad as was pictured, and will feel quite happy about it.

Just as in the treatment of younger patients, proper diagnosis and case analysis are the first important steps toward proper treatment of adults. Good models, photographs, x-rays (including cephalometric views), and a complete case history are essential. The cephalometric x-rays, many times, will be necessary to determine the freeway space and path of closure. Through the means of cephalometry, we have available a method of study with which the facial growth of the individual can be charted and any peculiar bony disturbances or disproportions discovered. Through such studies we are able to explain why certain faces simply do not have the potential for a beautiful result.

A cephalometric study may also show the indication or contraindication for extractions as a part of treatment in a particular case.

Where possible to determine, it is also helpful to know the causes for the malocclusion. We must determine whether it is due to local causes, such as loss of teeth causing a mutilated occlusion, or to constitutional or hereditary factors, such as disease or endocrine unbalance. It cannot be stressed too strongly that in no case should adult treatment be started unless the patient is in a good state of health. If chronic gingivitis or periodontoclasia is present, it is important that the condition be under control before treatment is started.

TREATMENT

The question of type of appliances will be discussed only briefly because I feel that the case analysis and the decision as to what need be accomplished are the important details, and not which appliance or mechanism is to be employed. Stuteville,[18] I feel, gave a fine description of the "proper appliance" when he said, "The best appliance for a given case is the simplest one that will correct the malocclusion in the shortest time with a minimum of trauma to the teeth and supporting structures."

Oren Oliver and his colleagues, using the labiolingual technique and Oliver guide plane, have shown a great many satisfactorily treated adult cases. Joe Johnson and his disciples have also shown many beautifully treated cases using the twin wire mechanism. Dr. Crozat and others using the various removable appliances have shown many cases brought to most satisfactory conclusions, and Dr. Tweed and his followers have shown many beautifully treated cases using the edgewise mechanism. It seems that the secret is not so much which mechanism was used, but rather the manner in which the mechanism was put to use. If one knows where he wants to go, he usually finds out how to get there. Some find travel by plane suits them best, others by train, and still others by automobile. They all arrive at the same destination, and, depending upon many factors, each mode of travel may be best for a certain time or place or person. So should it be, it seems, with orthodontic appliances. If one is well indoctrinated in diagnosis and analysis, and understands the objectives, he will find the modus operandi that best suits the particular case. There seems to be a place in the treatment of adult malocclusion for all of the various types of appliances, and the years of experience best show which is the most suitable for a special type of case in the hands of a particular operator.

In discussing treatment, the question of extraction plays an important part. It appears that judicious extraction followed by careful treatment is indicated and necessary in many cases in order to secure a favorable result in a reasonably short period of time. The literature is full of material regarding the pros and cons concerning the extraction question,[24-31] and not too much time need be spent in review.

Kingsley,[3] to my mind, best discussed the extraction question back in 1880 when he said, "The articulation of masticating organs is much more important than their number, and a limited number of grinding teeth fitting closely together will be of greater benefit to the individual than a mouthful of teeth with the articulation disturbed. It is often better to extract a malposed tooth than disturb a whole arch to bring it into line."

Calvin Case, George Grieve, John Hunter, and many others of the pioneers in orthodontics were advocates of extraction of certain teeth in order to obtain better dentofacial harmony.

Bernard Boudet,[2] writing an article in 1757, may have been the first to recommend the extraction of four first premolars for the correction of malocclusion.

It remained, however, for Charles Tweed[31] to popularize the extraction principle and set out a definite philosophy of treatment. His principles of treatment were based on the idea of uprighting the lower incisors over basal bone at or near 90 degrees, plus or minus 5 degrees, to the lower border of the mandible. In those cases in which it is found to be impossible to upright the teeth and place them over the available basal bone, it is necessary to extract certain teeth in order to secure additional space to align the remaining teeth over the available bony support. Facial lines then seem to come into more beautiful harmony, and a more stable occlusion seems to be produced. Dr. Tweed shows several case reports of patients treated in their twenties and thirties in which four premolars were extracted as a part of treatment procedure, and facial lines as well as tooth occlusion were greatly improved.

In sacrificing all of the four first premolar teeth, in the treatment of bimaxillary protrusion, Dr. Tweed indicates that the correct interpretation of Angle's "line of occlusion" has been complied with except for the one requirement of a full complement of teeth; however, most of the time, when extraction is not a part of treatment, several of the requisites of a good occlusion are lacking.

Lowrie Porter,[32] I feel, expressed the keynote regarding extraction as a part of treatment when he stressed the point that "the orthodontist advocating judicious extractions must follow with meticulously careful treatment in which all spaces are closed and the adjacent teeth in an upright condition. Improper treatment after extractions may result in a condition worse than the original malocclusion."

Therefore, it must be strongly pointed out that extractions as a part of treatment procedure must be undertaken only after a most careful case analysis, and then only by those orthodontists who are capable of employing the proper mechanical procedures necessary to close the resulting spaces properly.

Adults will undertake treatment of possibly a year, or perhaps two years, but will generally refuse treatment of longer duration. Extraction of certain teeth in indicated cases followed by proper treatment not only permits us to perform a service to the patient which is almost impossible to render in any other way, but also allows this treatment to be done in a reasonably short period of time.

In treating adults, the orthodontist has a tremendous opportunity of service for the health of the patient in cooperation with the periodontist, prosthodontist, oral surgeon, and general practitioner of dentistry. He also can do much to make a person's facial lines and contours more pleasing and change an unsightly face into a pretty one, thus bringing untold joy into many lives and correcting what might well be a serious psychosomatic disturbance.

Therefore, I feel it behooves us to discuss adult treatment in its relationship to the other phases of dentistry.

ORTHODONTICS AND PERIODONTAL DISEASE

According to Sidney Sorrin,[33] one of the country's leading periodontists, "Few people have sufficient resistance to withstand the consequences of malocclusion for an indefinite period. The usual result is the breakdown of the supporting tissues of the teeth sooner or later unless the traumatic occlusion is corrected."

Many times patients suffering from a malocclusion involving pathologic stress in certain areas, and resulting in periodontal disturbance, have been treated surgically, or with medicaments, by their dentists. This can be only a temporary remedy unless the teeth are brought into proper function through orthodontic or prosthetic means as the case needs indicate.

Clifton O. Dummett[34] has well discussed the close relationship necessary between the periodontist and the orthodontist if many patients are to secure the finest care and treatment. He divides the treatment of periodontal disease into three phases in which orthodontics can be of great aid to periodontics:

1. Removal of responsible factors
2. Elimination of symptoms
3. Institution of measures for preservation of oral health

There are a great many conditions causing periodontal disturbances that can and should be corrected through orthodontic aid. Some of these are:

1. Correction of migration and the closing of minute spaces in order to prevent food impaction.

2. Irregular alignment of teeth or crowding which causes a forcing together of the supporting tissues.

3. Bimaxillary protrusions in which the lower incisors are well off the apical base and destruction of the bony support is commencing, as well as recession of the gingival tissues.

4. Deep bites causing tissue irritation.

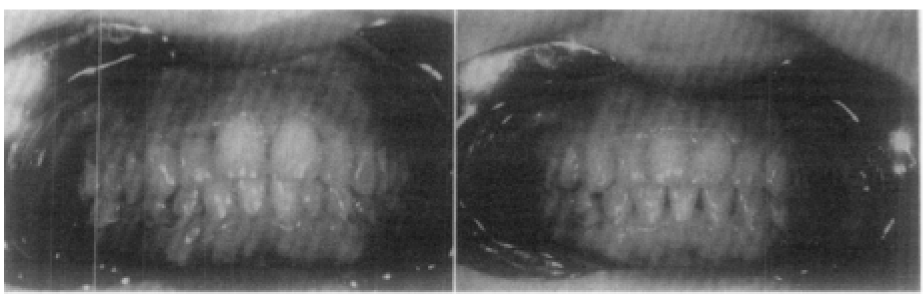
The gingival tissues as well as the entire denture can be kept in good health if the teeth are in their proper position and the jaws in good relation to each other.

In the treatment of these cases, we must first be certain that the acute periodontal disturbance has been cared for, and throughout the course of treatment we must carefully check and care for the supporting tissues. If treatment is not carefully done, further periodontal disease will occur.

In certain cases of crowding or buckling of the lower incisors with an attendant gingivitis, removal of one of the incisors might be indicated and the remaining teeth brought together. In so doing, the gingival tissues respond more readily to treatment, and the chronic gingivitis disappears. A careful case analysis is necessary before recommending this procedure.

CASE 1.—Fig. 1, *A* shows this type of condition in a woman aged 27. One lower incisor was removed, and the remaining incisors were banded. The upper central incisors had been previously mutilated by improper dentistry and so these were reduced in mesiodistal width and retracted with a high labial arch.

Fig. 1, *B* shows the healthy gingival tissues six months after removal of appliances. Case treatment was completed in ten months.



A. *B.*

Fig. 1.

Deep overbites also may be the cause of periodontal disturbance.[35-38] In such cases of deep overbite, careful x-ray examination should be made to determine if beginning alveolar absorption is present, and, if so, treatment to help correct the overbite is indicated.

CASE 2.—Fig. 2 (J. H.) shows such a condition in a man aged 30 years. In addition to beginning periodontal involvement, palatal tissue irritation had commenced. An upper premolar and lower incisor were extracted in order to have sufficient space to align remaining teeth. Final models (Fig. 2, *B*) were taken after fourteen months of treatment.

The spreading or spacing of upper or lower anterior teeth, due to traumatic occlusion in one or more of the occlusal movements, is frequently concomitant with periodontal pockets around the incisor teeth. A deep overbite is usually associated with these conditions and must be treated along with the protrusion correction.

CASE 3.—Fig. 3, *A* shows another case of beginning periodontoclasia in a man aged 29. The upper incisors were in linguoversion to the lower incisors, which had caused them to protrude and elongate. Beginning bone destruction was evident in the incisor and molar areas due to the traumatic occlusion. Johnson bands were placed on the lower

A.

B.

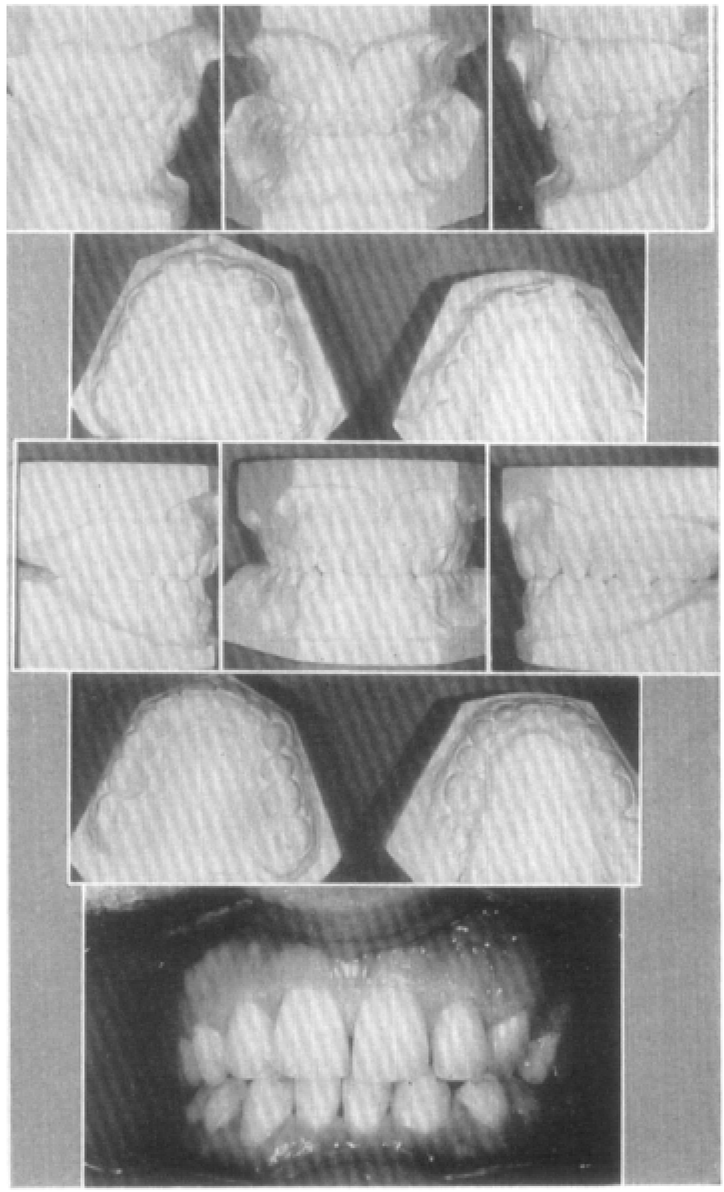
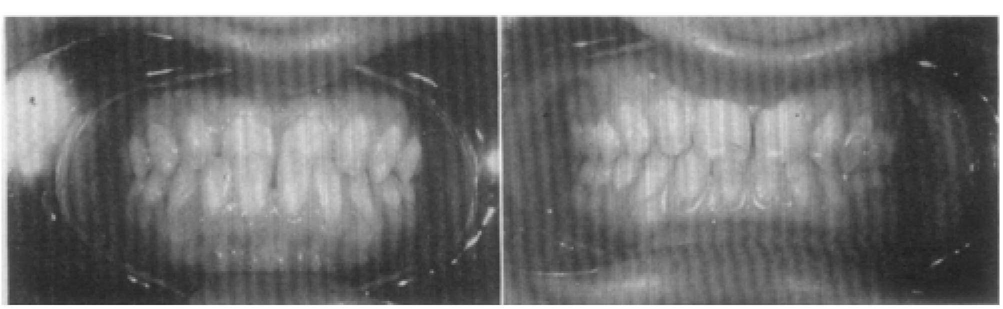


Fig. 2.



A. B.

Fig. 3.

incisors and a twin arch was used. An upper lingual arch was used above, and Class III elastics were used to correct the alignment. Fig. 3, *B* shows the result one year after treatment was completed. Six months' treatment was required.

ORTHODONTICS AND GENERAL DENTISTRY[39-46]

A large portion of a general dental practice deals with prosthetic replacements for patients in the form of fixed or removable bridgework.

In many cases, simple movement of teeth that have migrated after loss of neighboring teeth will be necessary in order to secure the best prosthetic result. In other cases, movement of certain teeth that are protruding or out of the line of occlusion will make the finished prosthesis more pleasing. The spreading of the incisors due to congenital absence of lateral incisors makes for an unsightly condition that simple orthodontic treatment can correct favorably for esthetic replacements.

In certain cases where the teeth are in poor axial inclination, the prosthetic appliance acts as a continuous "orthodontic" appliance, eventually causing loss of other teeth and, thus, larger restorations. Correcting the axial inclination of these teeth prior to prosthesis would prevent many such conditions. Many case reports are available showing the beautiful harmony and satisfactory dentures that can be obtained through combined ortho-prosthodontist cooperation.

It is essential that there be a fine spirit of cooperation between the dentist performing the prosthetic work and the orthodontist. Frequent consultations are indicated, and, in those cases in which fixed bridgework is indicated, the abutment teeth should be prepared and the bridge made ready while the teeth are being retained in their position by appliances.

The orthodontist must use judgment and ingenuity in the treatment of such cases, as a good, esthetically pleasing, functional occlusion should be the goal, instead of a so-called "ideal" occlusion.

ORTHODONTICS AND ORAL SURGERY[47-51]

Many deformed occlusions and disfigured faces can be best helped only through the cooperation of the orthodontist and the oral or plastic surgeon. At times patients suffering fractured jaws will require the aid of orthodontic appliances for proper positioning of the displaced fragments. However, it is in the case of mandibular protrusions or true Class III malocclusion faces that surgical interference has its preferred close relationship with orthodontics. The extreme Class III face, or "ultraprognathous" mandible as Lifton[52] has called it, is usually an unsightly one, and the occlusion presents a severe problem as far as mastication is concerned.

Orthodontic appliances can do only part of the treatment in these cases, and surgical correction is necessary in order to secure a beautiful and lasting result. The various surgical operations are not within the scope of this study; however, it should be emphasized that such treatment is a radical procedure and the case demands much study by the orthodontist and surgeon before being done. The literature shows many successfully completed cases of this nature and the results achieved well warrant the consideration of such procedure.

Abraham Goldstein[53] reported a group of seven such cases from age 20 to 29 representing a sample of more than twenty cases. Some of the conclusions he reached are:

1. Evidence points to the condylar cut being the most successful.
2. The edgewise mechanism is well suited for best maintenance of the new position.
3. Occlusal function is good after treatment.
4. The operation should be performed only on an adult as growth must be complete if permanence of result is expected.
5. Some postoperative orthodontic treatment is usually indicated for best improvement.

Kanthak and Hamm[54] divide the surgical approach into three groups:

1. Bicondylar resection
2. Resection of the body of the mandible
3. Osteotomy of the ascending rami

They further show the importance of combined cooperation when they say:

> We have produced our best results by working in conjunction with an orthodontist who places arches on both upper and lower jaws, banding sufficient teeth to assure stability in the appliance. The teeth may be moved preoperatively to a position where good interdigitation will be attained following mandibular section. After the osteotomy, the arch bars are used to fix the jaws firmly in the desired position. Following healing of the mandible in the new position the orthodontist again utilizes the appliances on the teeth to adjust the occlusion to the best possible state. This eliminates the necessity for grinding the occlusion in the majority of patients and permits attaining a more satisfactory chewing surface. The combined orthodontic-surgical approach is capable of producing brilliant results in selected cases.

These cases present dramatic results and well warrant our consideration of cooperation with a well-qualified oral surgeon.

Mandibular displacements are also frequently a source of worry to the dental surgeon. The insertion of bite planes, in such conditions, in order to establish correct vertical dimension, will often prevent further overclosure and irritation in the condyle region. Cephalometric tracings[55] to determine path of closure and the freeway space or rest position are necessary aids for the proper diagnosis and treatment of such disorders.

ORTHODONTICS AND PSYCHOSOMATICS[56, 57]

The problem of esthetics plays a most important role in the mental health of patients. Unsightly teeth, heavy protrusive facial features, and tenseness of the facial musculature due to denture disharmony all may cause mental conflicts. The field of psychosomatic medicine has grown rapidly in recent years because it has been shown that emotions alter the physiology of the body and may cause pathologic changes to take place.

Many cases of unsightly protrusions and positions of the teeth have caused patients to suffer a great deal of embarrassment and mental anguish.

In evaluating the need for adult treatment of malocclusion, the emotional make-up of the patient should be studied and taken into consideration. The orthodontist has the opportunity in many cases to remove emotional tension by securing a pleasant smile and improving facial appearance.

An adult usually has come seeking orthodontic aid only because he is keenly aware of his deformity, and because it is a source of constant personal humiliation. I have found adults to be excellent patients, very cooperative, and most appreciative. Case 4 is such an individual.

CASE 4.—Fig. 4 (A. E.) shows a protrusion in a young woman aged 25 who had received orthodontic treatment several years previously. The orthodontist had extracted the two upper first premolars and considered the case complete as shown in Fig. 4, *A*. This was far from being completed because the patient, an attractive girl, was developing an obsession with regard to her protruding teeth, and rarely smiled.

Extracting the upper premolars and permitting the posterior teeth to come forward, as was done, only aligned the teeth. From this, it can be seen that unless extractions are followed by careful, judicious, and indicated treatment, it is far better *not* to treat, and certainly better *not* to extract.

In our treatment of the patient mentioned, the lower first premolars were extracted and complete edgewise mechanism was used for eighteen months to secure the result shown (Fig. 4, *B*). Final models taken three years after all appliances were removed show denture stable, and x-rays show teeth and supporting structures in better condition than before treatment some five years earlier.

The following letter received from this patient at the end of treatment, I feel, best tells the adult orthodontic story:

Dear Dr. Goldstein:

Not long ago you asked me if I considered the time, discomfort, and money spent on having my teeth straightened worthwhile. I hope this will answer your question.

Now when I proudly look into the mirror it doesn't seem possible that a scant year ago I was the possessor of crooked teeth. They "stuck out" which caused me to tug at my upper lip trying in vain to hide the protrusion. I was painfully self-conscious about it. When I laughed, I either threw up one hand to hide my face, or I kept my mouth closed, which caused my jaws to ache. I was constantly embarrassed, suffered untold agonies and acquired an inferiority complex along the way—all because I had buck teeth! I realized, too late I thought, the importance of having beautifully straight teeth. It became an obsession; it became the first thing I noticed when I met anyone. If someone mentioned it, even kindly, I resented it, bitterly at first; then with an apologetic attitude, I confided that it was too late to do anything about it. And yet, I didn't really believe that; I clung to the idea that someday I would find someone who could help me.

Were you ever called "Buck"? Well, I was. It not only hurt, it made me mad! So mad that I promised myself that someday—somehow, I would have straight teeth. And I have! When I rang your doorbell I expected shortly to come bounding out with yet another rebuff . . . and when you said "I believe I can help you," I could have cried from sheer happiness. . . . I could have hugged your neck. With difficulty I refrained from doing either. Even though they were sound, for years every tooth in my head ached. They ached when I got up in the morning . . . they were still aching when I went to bed. I lay awake for hours trying to harness my tongue so that I wouldn't go to sleep pushing into my front upper teeth. I had an idea this caused them to move outward; in fact, I have even felt them moving. I sometimes suffered an acute and urgent desire to grab my mouth with my hand and try to push my front teeth back into my mouth. I usually had this urge when out in public, and was rendered helpless by my inability to do anything about it.

The day you put bands on my two most prominent front teeth I was happier than when I got my Byelo doll, my skates and bicycle and at being able to skip the first grade. There were two reasons why I waited until I was twenty-five to have my teeth straightened. One was that I did not have the money. Then, there didn't seem to be a dentist who would tackle the job. "Impossible" they termed it.

Somehow I am always surprised when I hear a person say "Oh, I'd have my teeth straightened but they don't look as bad as that bill would when I got it." Why, I wouldn't swap my straight teeth for all the minks in Alaska. (Or wherever little minks live.) To me it's the safest and wisest investment I know, for who can dispute the fact that a beautiful smile is one of man's or woman's greatest assets?

For over a year I withstood the jeers and skepticism of friends and acquaintances. "My dear, you don't really mean you're going to let him pull some of your teeth?" "Good heavens, but you're crazy, I wouldn't think of doing such a thing, you'll be sorry." "Why, I had a friend who wore braces and every one, mind you, every one of her teeth got loose and they've been that way ever since, and are rotting out!" "I wore 'em when I was little and on every tooth where the bands were I've got a cavity—it absolutely ruined me. Of course, maybe your dentist knows more than mine did, but I doubt it." "I'd think twice before I'd let him work on me—but, of course, it's your teeth, your money and your business." I found myself confiding my tooth experiences to strangers in elevators, on trolleys, and in theatre lines. Whenever I met another set of braces we always smiled knowingly as though members of the same secret order.

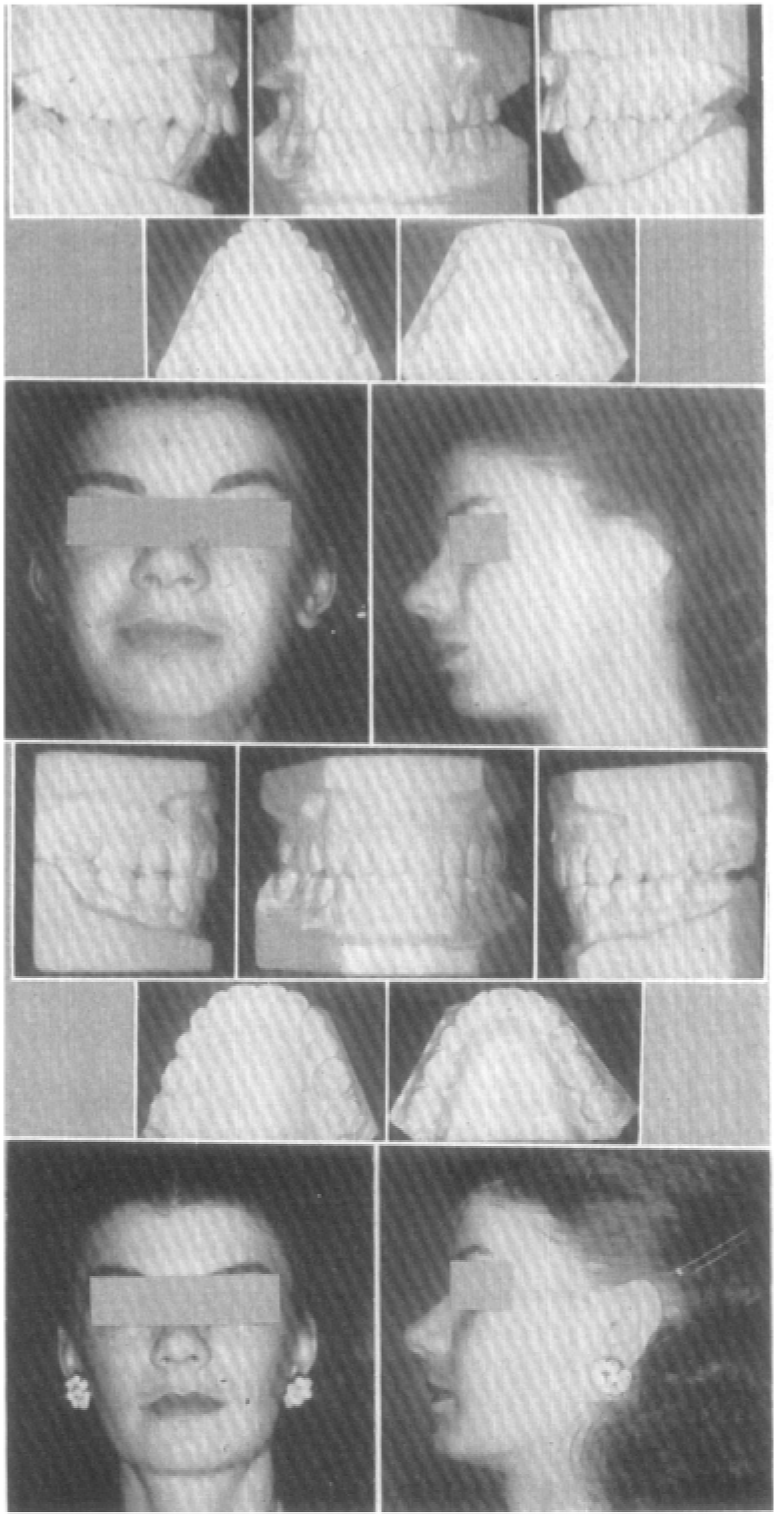
In the beginning, I was impressioned, x-rayed, photographed, grilled, numbered and filed. Since then I have been bewildered, confused, disconcerted, difficult, tortured, harassed, distressed, miserable, injured, hurt, damaged, impaired, scathed, marred, defaced, abused, pleased, delighted, ecstatic, exultant, buoyant and victorious. You have been firm, adament, severe, stern, unfeeling, exacting, gay, competent, confident and grand. If I had another eighteen months of the same I would submit quietly and happily. I'm proud of every band, every wire, every hour of discomfort because I feel that I'll be chipping my teeth at the people who called me "Buck" when they're putting theirs away for the night in a glass of water.

Gratefully yours,

/s/ Anita

In addition to the personal satisfaction derived from receiving such a letter, the orthodontist can better appreciate the importance of performing treatment on these older patients.

The following case reports show a few additional cases in which facial and mouth changes occurred, greatly improving the appearance, as well as the entire personality, of the people involved. Pleasant smiles on faces that used to frown to cover disfiguring dental deformities can do much to achieve general happiness.



A.

B.

Fig. 4.

CASE 5.—Fig. 5 (J. J.) shows an extreme Class II, Division 1 protrusion with crowding of the anterior teeth. The patient was at the lower level of the adult age group, 17 years, but the case has been included because the patient had been told by certain orthodontists on previous occasions that she was too old for correction. Extraction of four first premolars followed by complete edgewise Tweed therapy gave the result shown in approximately one year's time.

CASE 6.—Fig. 6 (C. F.) shows a Class II, Division 1 (subdivision) protrusion of a young woman aged 28. She had a most protrusive face, as the photographs show, and her teeth were most prominent. Approximately two years of treatment with the edgewise mechanism brought this face and denture into a nice state of balance. It was necessary to extract the four first premolars in order to secure a satisfactory esthetic and functional result. Edgewise bracket bands were placed on all teeth during the course of treatment, and the spaces were closed with vertical loop sectional arches. Then, round and rectangular arches were used to complete the treatment. In order to correct the unilateral Class II molar relation, Class II elastic mechanics was first used and then, after a near Class III relation appeared on the previous normal relationship side, this side was switched to Class III elastic mechanics, and Class II was continued on the other side. The final result shows a pleasing muscular and facial balance.

CASE 7.—Fig. 7, *A* (H. F.) shows a Class II, Division 2 malocclusion in a young woman aged 28 who was extremely conscious of the condition and considered it a decided handicap in her chosen profession of law. In this case, only the upper arch was treated. Second molars were removed, since the x-rays indicated the third molars were in proper condition, and a Johnson twin wire mechanism was placed on the upper arch and a headcap used at night to correct the protrusion. Fig. 7, *B* shows the result after fourteen months of treatment. Examination three years after all appliances were removed found the denture with both upper third molars erupted into proper position. The lower arch was left completely alone as it seemed to be a bit forward, and it was feared that Class II elastics might endanger the complete lower arch. The final facial photograph, three years after treatment, shows the pleasant result.

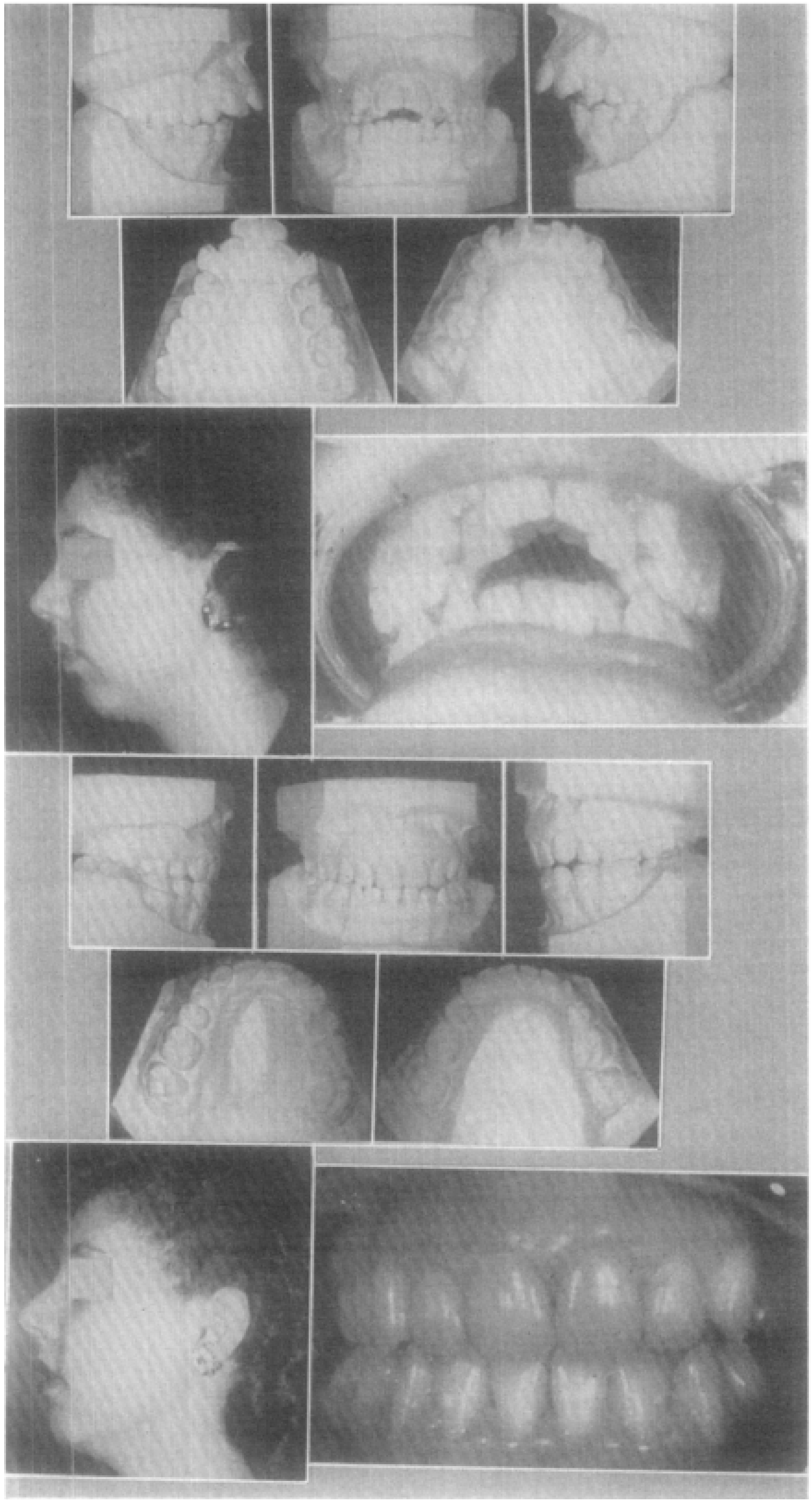
CASE 8.—Some patients show extreme muscle tenseness about the face, making a nice facial appearance almost impossible, and Fig. 8 (A. B.), female patient, aged 24, shows such a case. The lower right cuspid had been lost previously, so three premolars from the other segments were extracted. Final photographs show results after sixteen months of active treatment using edgewise mechanism. The relaxation of the face, as well as the balanced occlusion, is plainly evident.

CASE 9.—This is another case of protrusion in a young woman aged 22. Fig. 9, *A* shows models at the start of treatment, and intraoral view with attending gingivitis. History indicated previous orthodontic treatment of two years' duration at the age of 12. The four first premolars were extracted and edgewise bands and technique used to treat. Final models show the case at the time retainers were inserted. Sixteen months of treatment was required. Fig. 9, *B,* final intraoral photographs, shows healthy tissues.

These cases were presented not because they were unusual, but rather to show examples of types of adult cases that are especially adaptable for successful treatment. They emphasize that treatment can be carried out to a fine conclusion if carefully planned and instituted.

SUMMARY AND CONCLUSIONS

The adult dentition when in malocclusion or malfunction may be in need of several types or combinations of dental treatment in order to restore properly the health of the mouth and patient. It is indicated not only for



A.

B.

Fig. 5.

A.

B.

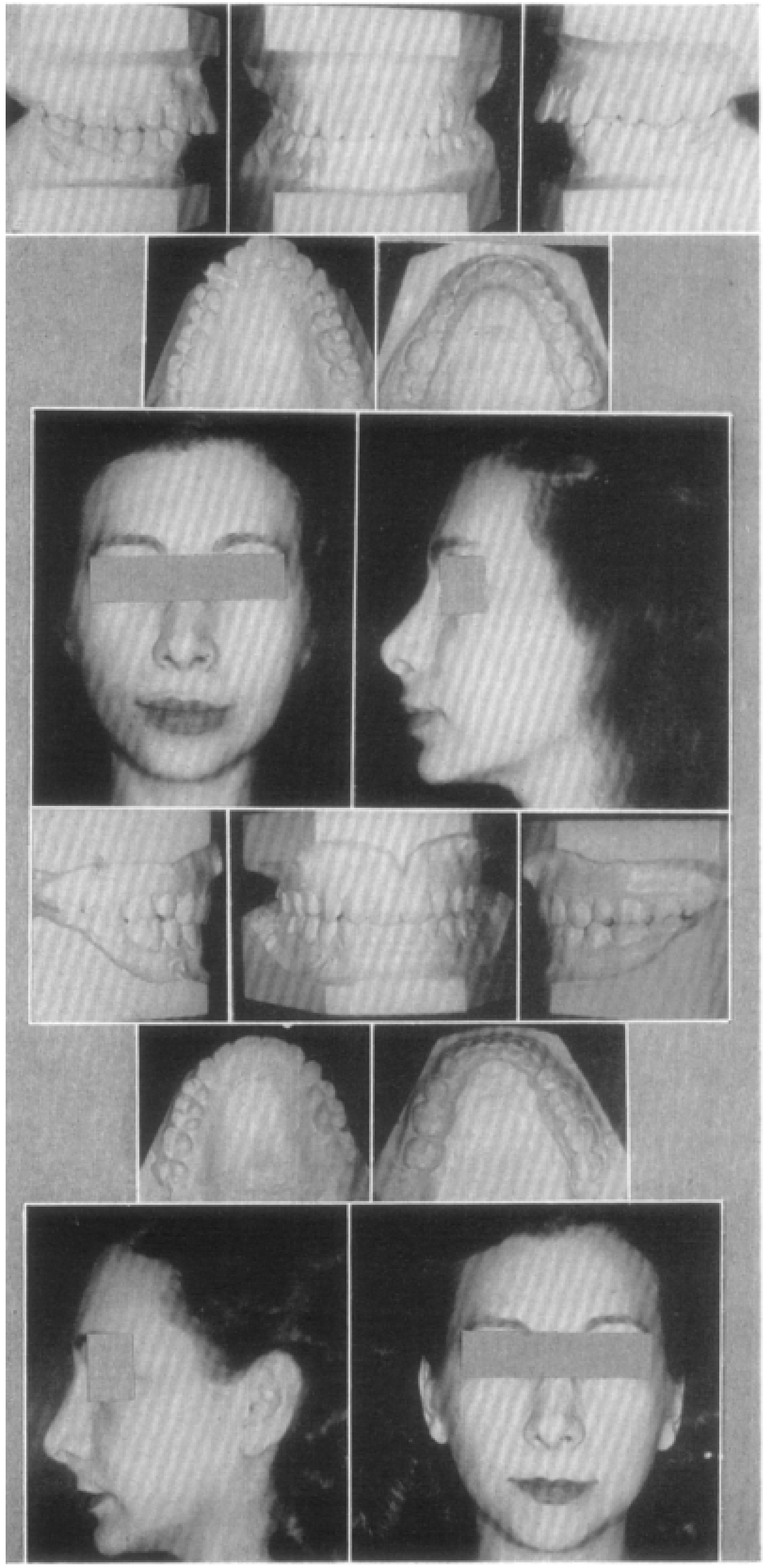
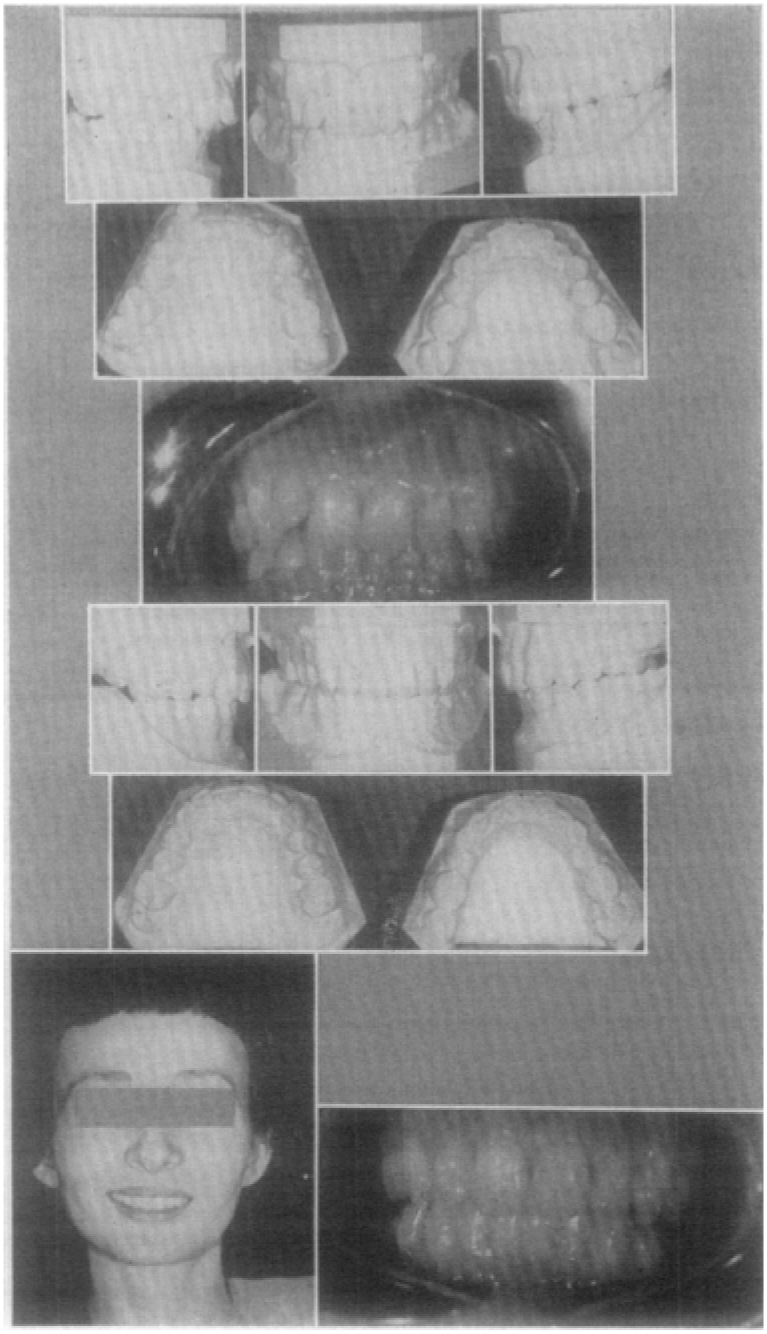


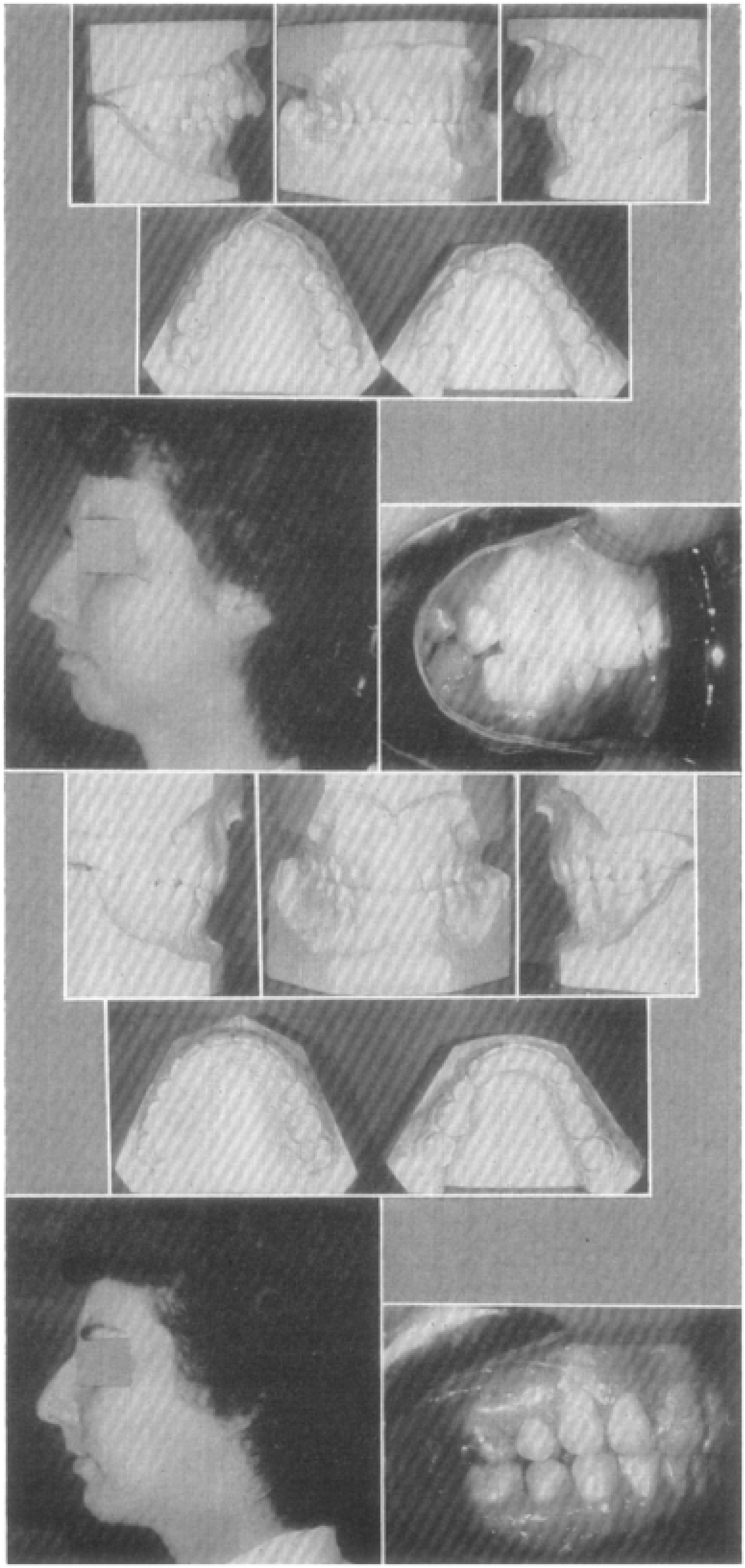
Fig. 6.



A.

B.

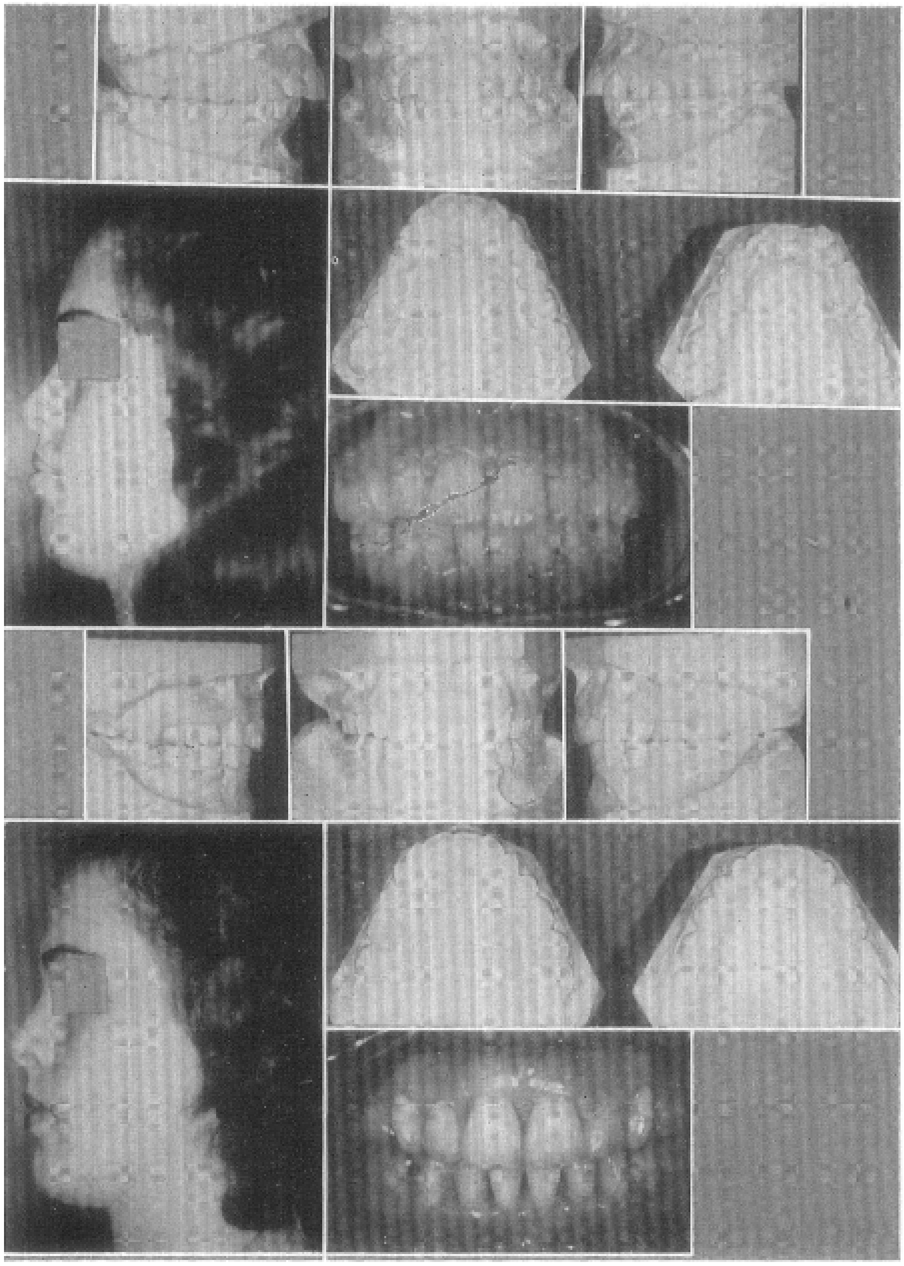
Fig. 7.



A.

B.

Fig. 8.



A.

B.

Fig. 9.

esthetic purposes, but also for the remedy of certain mouth diseases—periodontoclasia, caries, certain pathologic disturbances, and mandibular displacements. Each field of dentistry is dependent upon an allied one and the neglect of one field, whichever it might be, will cause the health of the patient to suffer.

We must impress the various specialists of dentistry and the general practitioner that we must be concerned with the whole patient and not our own special field of interest.

1. There is no age limit for orthodontic correction. The quality of the supporting bone and tissues and the judgment of the operator are the determining points, instead of chronological age itself.

2. Certain growth deformities of the mandible must be treated by a combination of orthodontics and surgery in order best to correct facial deformity and acquire good dental occlusion.

3. Extraction as an adjunct to treatment plays a necessary and vital role in the treatment of adults.

4. Much can be done to improve disharmony of related structures in adult life through the means of orthodontics.

5. Adults must be treated with more caution than children, and should be watched more closely through frequent x-ray examinations.

6. Satisfactory results are obtainable in the accurately diagnosed and properly treated adult cases.

7. The broadening of our scope of adult treatment is important and necessary.

Dr. Leuman Waugh[20] in 1927 made the statement which I feel holds even more weight today when he said, "Very much is possible in adult cases and treatment is the duty of the orthodontist." Yes, I agree with Dr. Waugh that it is our duty to try to help those in need of correction, where there is some hope for success, if we are to continue to maintain our position as integral members of the healing arts. We must view the patient as a whole and think of our own specialty in the over-all relation to the health and well-being of the patient. In this way orthodontics offers a tremendous opportunity for service to humanity.

REFERENCES

1. Pierre Fauchard Academy Poll: D. Survey **23**: 1076, 1947.
2. Weinberger, Bernhard W.: Orthodontics, An Historical Review of Its Origin and Evolution, St. Louis, 1926, The C. V. Mosby Company, vols. 1 and 2.
3. Kingsley, Norman W.: Oral Deformities, New York, 1880, Appleton & Company, p. 63.
4. Jackson, Victor Hugo: Orthodontics, Philadelphia, 1904, J. B. Lippincott Company, p. 70.
5. Guilford, S. H.: Orthodontia, ed. 4, 1905. Press. T. G. Davis, p. 37.
6. Dewey, Martin and Anderson, George M.: Practical Orthodontia, St. Louis, 1935, The C. V. Mosby Company.
7. Salzmann, J. A.: Principles of Orthodontics, Philadelphia, 1950, J. B. Lippincott Company.
8. Abraham, Samuel: Case Report of Dento-Facial Orthopedia, Dental Cosmos **78**: 619, 1936.
9. Jacobs, Walter H.: Adult Orthodontics, Dental Items Interest **66**: 970, 1944.

10. Johnson, Leland R.: Compromise Treatment in an Adult, INT. J. ORTHODONTIA **21**: 572, 1935.
11. Pullen, Herbert A.: Treatment of an Adult Open-Bite Case by Grinding the Occlusal Surfaces of Posterior Teeth, INT. J. ORTHODONTIA **16**: 1187, 1930.
12. Silver, Edward I.: Treatment of a Class III Adult Case with the Use of Vulcanite Bite Blocks, INT. J. ORTHODONTIA **23**: 506, 1937.
13. Stone, Sidney P.: Orthodontic Treatment of a Bilateral Distoclusion Adult Case with Extreme Retrotrusion of Maxillary Centrals, Alpha Omegan **11**: 14, 1946.
14. Marshall, David: Orthodontics for an Adult, New York State D. J. **16**: 513, 1950.
15. Strang, Robert H. W.: Textbook of Orthodontia, Philadelphia, 1933, Lea & Febiger.
16. Oppenheim, Albin: Human Tissue Response to Orthodontic Intervention of Short and Long Duration, AM. J. ORTHODONTICS AND ORAL SURG. **28**: 263, 1942.
17. Kronfeld, R.: Histopathology of the Teeth and Their Surrounding Structure, Philadelphia, 1933, Lea & Febiger.
18. Stuteville, O. H.: Summary Review of Tissue Changes Incident to Tooth Movement, Angle Orthodontist **8**: 1, 1936.
19. Moore, George R.: Is There an Age Limit for Orthodontic Treatment? J. Michigan State D. Soc. **25**: 144, 1943.
20. Gray, B. Frank: Is Orthodontic Treatment Contraindicated? INT. J. ORTHODONTIA **13**: 1013, 1927.
21. Johnson, A. Leroy: Orthodontic Education, Dental Cosmos **62**: 1186-1194, 1920.
22. Porter, Lowrie J.: Conservatism in Orthodontic Procedure and Appliances, AM. J. ORTHODONTICS AND ORAL SURG. **33**: 125, 1947.
23. Johnson, Ernest L.: The Frankfort-Mandibular Plane Angle and the Facial Pattern, AM. J. ORTHODONTICS **36**: 516, 1950.
24. Guilford, S. H.: Extractions—When Justifiable in Connection with Orthodontic Operations, Dental Cosmos, September, 1905.
25. Tweed, C. H.: Indications for the Extraction of Teeth in Orthodontic Procedure, AM. J. ORTHODONTICS AND ORAL SURG. **30**: 405, 1944.
26. Case, C. S.: Question of Extraction in Orthodontia, Dental Cosmos **54**: 137-157, 1912.
27. Strang, R. H. W.: The Advisability of Extraction as a Therapeutic Aid in Orthodontics: Affirmative, AM. J. ORTHODONTICS AND ORAL SURG. **33**: 141, 1947.
28. Waugh, Leuman M.: The Advisability of Extraction as a Therapeutic Aid in Orthodontics: Negative, AM. J. ORTHODONTICS AND ORAL SURG. **33**: 141, 1947.
29. Berger, H.: The Problem of Extraction in Orthodontics, AM. J. ORTHODONTICS AND ORAL SURG. **31**: 557, 1945.
30. Chapman, H.: A Note on Extraction in Orthodontic Cases, INT. J. ORTHODONTIA **20**: 561, 1931.
31. Tweed, Charles H.: A Philosophy of Orthodontia Treatment, AM. J. ORTHODONTICS AND ORAL SURG. **31**: 74, 1945.
32. Porter, Lowrie J.: Orthodontic Extractions, Frater Psi Omega **44**: 124, 1943.
33. Sorrin, Sidney: Traumatic Occlusion, Dental Items Interest **5**: 425, 1931.
34. Dummett, Clifton O.: Orthodontics and Periodontal Disease, J. Periodontol. **22**: 34, 1951.
35. Offer-Spitz, Age: Prevention and Treatment of Oral Diseases of Adults by Orthodontic Means, AM. J. ORTHODONTICS AND ORAL SURG. **31**: 391, 1945.
36. Wolfson, Abraham: Deep Bites in Adults, AM. J. ORTHODONTICS AND ORAL SURG. **24**: 120, 1938.
37. Howes, Ashley E.: Altering the Overbite—A Model Study of Two Adult Cases, AM. J. ORTHODONTICS AND ORAL SURG. **28**: 173, 1938.
38. De Van, M. M.: Methods of Procedure in Treatment of Overbite in Adult Dentition, J. Canadian D. A. **2**: 371, 1936.
39. Stein, S. Harrington: Adult Orthodontics, Dental Cosmos **76**: 611, 1936.
40. Burne, Wm. McGill: Adult Orthodontia from the Standpoint of the General Practitioner, Dental Items Interest **10**: 216, 1936.
41. Begg, P. Raymond: The Relationship of Orthodontics to General Practice, AM. J. ORTHODONTICS AND ORAL SURG. **31**: 507, 1947.
42. Flint, Wilson R.: Orthodontics for Adults, D. Survey **23**: 872, 1947.
43. Kohn, Leonard: Mouth Rehabilitation: Orthodontics and Prosthesis, J. Am. Dent. A. **30**: 398, 1943.
44. Hlavoc, Charles W.: Orthodontics as an Aid to Prosthodontics, AM. J. ORTHODONTICS AND ORAL SURG. **27**: 41, 1941.
45. Oliver, Oren A.: Orthodontics as a Supplement to All Restorative Dentistry, AM. J. ORTHODONTICS AND ORAL SURG. **26**: 320, 1940.
46. Lussier, Earl F.: Adult Orthodontic Therapy: A Practical Aid to the General Practitioner, J. Am. Dent. A. **23**: 2102, 1936.
47. Lifton, Jacob C.: Orthodontics in Orofacial Prosthesis, AM. J. ORTHODONTICS AND ORAL SURG. **29**: 18, 1943.

48. Davis, Albert L.: The Role of Plastic Surgery in Relation to Orthodontics, Am. J. Orthodontics and Oral Surg. **19**: 1214, 1933.
49. Sikes, T. Edgar.: Orthodontics as an Adjunct to Oral Surgery, Am. J. Orthodontics **36**: 608, 1950.
50. Winter, Fred: Report on Treatment of Class III, Am. J. Orthodontics and Oral Surg. **26**: 346, 1940.
51. Reiter, Edward: The Surgical Correction of Mandibular Prognathism, Alpha Omega **14**: 104, 1951.
52. Lifton, Jacob C.: Orthodontic Procedures in Gross Dentofacial Malformation, Am. J. Orthodontics and Oral Surg. **33**: 325, 1947.
53. Goldstein, Abraham: Appraised Results of Surgical Correction of Class III Malocclusion, Angle Orthodontist **17**: 59, 1947.
54. Kanthak, Frank F., and Hamm, William G.: The Surgical Treatment of Growth Deformities of the Mandible, South. Surgeon **14**: 147, 1948.
55. Ford, James W., and Ford, William F.: Cephalometric Appraisal of a Treated Mandibular Displacement Case in an Adult Patient, Am. J. Orthodontics **36**: 222, 1950.
56. Ash, Arthur S.: Psychosomatic Consideration in Orthodontics, Am. J. Orthodontics **36**: 292, 1950.
57. Burstone, Marvin S.: The Psychosomatic Aspects of Dental Problems, J. Am. Dent. A. **33**: 862, 1946.
58. Herzberg, Ben: Personal communications.

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ORIGINAL ARTICLE CE

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Radiographic predictors for maxillary canine impaction

Ali Alqerban,[a] Reinhilde Jacobs,[b] Steffen Fieuws,[c] and Guy Willems[d]
Leuven, Belgium, and Riyadh, Saudi Arabia

Introduction: The aims of this study were to compare 3-dimensional cone-beam computed tomography (CBCT) images of patients with unilaterally impacted canines and to determine the possible radiographic factors for prediction of maxillary canine impactions. **Methods:** The sample consisted of 65 patients ranging in age from 9.6 to 13.8 years. The patients comprised 43 girls and 22 boys, with a mean age of 12.1 years and a median age of 12.2 years (±SD 1.23 years). Of the impacted maxillary canines, 32 were located on the right side and 33 on the left side. CBCT radiography was available for all patients. The diagnosis of a unilaterally impacted canine was determined from the patients' dental records as a unilateral failure of the canine to erupt at its appropriate site in the dental arch in contrast to normal eruption of the contralateral side. Radiographic follow-up assessment to identify unilateral impaction was performed for 1 year. The radiographic variables generated and the specific features investigated were collected with 3-dimensional CBCT imaging and compared between the impacted and the contralateral maxillary canines. **Results:** Statistically significant differences were found between the impacted and nonimpacted canines. Based on these results, clinical relevance and correlations among the variables—canine rotation, canine crown position, canine cusp tip to the midline and to the occlusal plane, canine angle to the midline, and canine angle to the lateral incisor—were considered as variables in a multivariable prediction model. A prediction model using CBCT for canine impaction was established (area under the curve, 0.965; 95% con dence interval, 0.936 to 0.995). Canine crown position, canine cusp tip to the occlusal plane, and canine angulation to the lateral incisor were the relevant predictors in this model. **Conclusions:** Prediction of canine impaction based on CBCT was excellent. The probability of canine impaction obtained from the prediction model can help orthodontists to define the optimal intervention method. (Am J Orthod Dentofacial Orthop 2015;147:345-54)

Impacted maxillary canines are a common problem in orthodontic practice, with up to 5% of patients seeking orthodontic treatment.[1] According to the literature, the incidence of female patients with maxillary canine impaction shows a strong prevalence and has been well documented.[2-4] Several local factors have been hypothesized for maxillary canine impaction, such as a narrow maxillary arch or a Class II Division 2 malocclusion.[5,6] A possible genetic origin for palatally displaced canines has also been indicated.[3,7] Palatally impacted canines are usually associated with other dental anomalies, such as congenital absence of the lateral incisors or the second premolars, and peg-shaped lateral incisors.[3,8-10] An impacted canine may cause root resorption of adjacent teeth, particularly the lateral incisor. Several studies have reported that incisor root resorption is more common in female patients than in males,[3,11-14] with wide variations in the severity among different racial populations.[15] Incisor root resorption is asymptomatic and usually diagnosed late in relation to the patient's age and the severity of resorption.[13]

The treatment of impacted canines is multidisciplinary and associated with prolonged treatment time and increased costs.[16] The choice of treatment is influenced by several factors, such as canine location, severity of impaction, patient age, and other patient considerations. Interceptive orthodontic treatment is often the first approach in growing persons for guiding the canine into a normal position and preventing tooth impaction.

[a]Visiting assistant professor, Department of Oral Health Sciences, University Hospital, University of KU Leuven, Leuven, Belgium; orthodontist consultant, Riyadh, Saudi Arabia.
[b]Professor, OMFS-IMPATH Research Group, Department of Imaging and Pathology, University of KU Leuven, Leuven, Belgium, and Maxillofacial Surgery, University Hospitals Leuven, Leuven, Belgium.
[c]Statistical consultant, KU Leuven – University of Leuven & Universiteit Hasselt, Interuniversity Institute for Biostatistics and Statistical Bioinformatics, Leuven, Belgium.
[d]Professor and head, Department of Oral Health Sciences, University Hospital, University of KU Leuven, Leuven, Belgium.
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Address correspondence to: Guy Willems, Department of Oral Health Sciences-Orthodontics, KU Leuven, University Hospitals Leuven, Kapucijnenvoer 33 box 7001, 3000 Leuven, Belgium; e-mail, guy.willems@med.kuleuven.be.
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The treatment sometimes consists of removal of the maxillary deciduous canines or is combined with creating spaces in the dental arch by distalization, extraction of the maxillary deciduous first molar, or maxillary expansion.[17-22] However, it has been found that extraction of only the deciduous canine is not effective.[22] Surgical exposure of the impacted canine is essential when interceptive treatment fails, usually requiring a combination of surgical and orthodontic interventions to bring the canine successfully into the dental arch.[21] Furthermore, older patients with impacted canines require more time and are more difficult to treat than younger patients.[21-26] A novel 3-dimensional (3D) classification system (KPG index) was developed as a method to classify and estimate the difficulty of treatment of impacted maxillary canines using cone-beam computed tomography (CBCT) images, without multiple measurements of angles and distances.[27] The reliability and the repeatability of this index have been proven in other studies to be easy and efficient.[26,28] However, the ef cacy in estimating treatment time based on the dif culty score is always difficult and still unknown.[28]

Early prediction and early diagnosis of impaction with 2-dimensional (2D) radiographs remains problematic. It is challenging to distinguish structures based on conventional 2D radiographs, which often lead to misinterpretations. CBCT images, by their nature, have significant advantages over 2D images.[10] When a 3D view is available, many diagnostic issues related to impacted canines can be easily answered. Potential complications of canine impaction include the need for CBCT images so that the orthodontist can understand the development of impaction and normal eruption. Several studies have investigated the possible predictors of canine impaction and orthodontic treatment choices with 2D radiographs.[11-14] Therefore, the aims of this study were to compare 3D CBCT images of unilaterally impacted canines with the normal contralateral sides, and to detect possible radiographic factors involved in maxillary canine impaction.

MATERIAL AND METHODS

This investigation was based on the radiographic records of patients who were referred for CBCT images. All patients were nonsyndromic and were selected if they had a unilaterally impacted maxillary canine. The sample consisted of 65 patients ranging in age from 9.6 to 13.8 years. They included 43 girls and 22 boys, with a mean age of 12.1 years and a median age of 12.2 years ($\pm$SD, 1.23 years). Of the impacted maxillary canines, 32 were located on the right side and 33 on the left side. The diagnosis of unilaterally impacted canine was determined from the patients' dental records as a failure of the canine to erupt at its appropriate site in the dental arch in contrast to normal eruption of the contralateral side. Radiographic follow-up assessment to identify unilateral impaction was performed for 1 year. The study protocol was approved by the medical ethics committee of the University of Leuven in Belgium (approval numbers B32220083749, S50910).

All patients had a CBCT scan with either of 2 CBCT systems. The rst involved a 3D Accuitomo-XYZ Slice View Tomograph (J. Morita Corp, Kyoto, Japan) with a voxel size of 0.125 mm (eld of view, 30 $\times$ 40 mm). Parameters included tube voltage of 80 kV, tube current of 3 mA, and scanning time of 18 seconds. The second system was a Scanora 3D CBCT (Soredex, Tuusula, Finland) with a voxel size of 0.2 mm (field of view, 75 $\times$ 100 mm), tube voltage of 85 kV, current of 10 mA, and scanning time of 3.7 seconds.

The protocol included evaluation of variables related to specific features obtained from the radiographic records, which were analyzed by 1 investigator (A.A.). The variables were categorized as the following.

Canine-related variables

1. Crowding in the maxillary anterior region.
2. The maxillary deciduous canine was assigned to 1 of 3 categories: missing tooth, where the deciduous canine had been extracted; present without root resorption; or present with root resorption.
3. Canine development was assigned to 1 of 4 categories based on root development: complete development, 75% of the root developed, 50% of the root developed, and 25% of the root developed.
4. Canine apex: open, closed, or dilacerated.
5. Detection of abnormalities, such as canine root resorption, mesiodens, peg-shaped lateral incisor, agenesis of permanent teeth, and impaction of other permanent teeth.
6. Canine rotation: mesiovestibular, distovestibular, mesiopalatal, or distopalatal.
7. Canine position in relation to adjacent teeth was determined from the CBCT images as palatal, buccal, or in the line of the arch.
8. Type of canine impaction was assigned to 1 of 3 categories: no impaction; vertical impaction, if the impacted canine was vertically inclined and covered with soft or bony tissue; and horizontal impaction, if the impacted canine was horizontally inclined and covered with soft or bony tissue.
9. The roots of the first premolar were categorized as single root, separated roots, or fused roots.

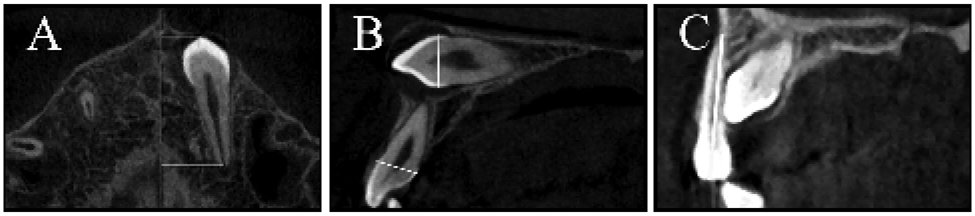

Fig 1. Cross-sectional CBCT images illustrating the reference lines of linear measurements: **A,** canine cusp tip and canine apex to the midline measured in the axial view; **B,** width of the canine and lateral incisor crown buccolingually measured in the sagittal view; **C,** length of the lateral incisor measured in the sagittal view.

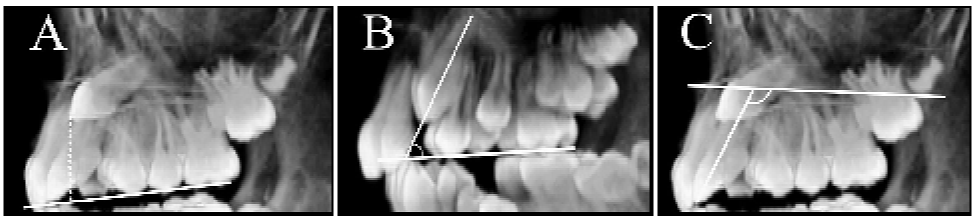

Fig 2. Cross-sectional CBCT images illustrating the reference lines of linear and angular measurements: **A,** canine cusp tip to the occlusal plane measured in the sagittal view; **B,** canine angulation to the occlusal plane measured in the sagittal view; **C,** lateral incisor inclination to the maxillary plane measured in the sagittal view.

10. Anterior apical area was recorded as optimal, small, or severe.
11. Contact relationship between the canine and adjacent teeth was assigned to 1 of 2 categories based on the categories suggested by Ericson et al[15]: contact, if the distance between the crown of the maxillary permanent canine and adjacent incisors is less than 1 mm; and no contact, if the distance between the crown of the maxillary permanent canine and adjacent incisors is more than 1 mm.

Linear measurements in millimeters

1. Canine cusp tip to the midline was measured in the axial view (Fig 1, *A*).
2. Canine cusp tip to the occlusal plane was measured in the sagittal view. The occlusal plane was defined as the line from the mesiobuccal cusp of the maxillary first molar to the incisal edge of the maxillary central incisor in the sagittal view (Fig 2, *A*).
3. Canine apex to the midline was measured in the axial view (Fig 1, *A*).
4. Width of the canine crown buccolingually and mesiodistally was defined as the distance from the mesial contour to the distal contour of the maxillary canine (Fig 1, *B*).
5. Width of the lateral incisor was measured buccolingually and mesiodistally at the cementoenamel junction (Fig 1, *B*).
6. Length of the lateral incisor from the incisal edge to the apex was measured in the sagittal view (Fig 1, *C*).
7. The mesiodistal space available for the canine between the lateral incisor and the first premolar at the occlusal level and at the apical thirds was measured in the axial view.

Angular measurements in degrees

1. Canine angulation to the midline, where the angle is formed by the long axis of the impacted canine and the midline of the maxilla in the coronal view (Fig 3).
2. Canine angulation to the lateral incisor, where an angle is formed by the long axis of the impacted canine and the long axis of the lateral incisor in the coronal view (Fig 3).
3. Canine angulation to the occlusal plane, where the angle in the sagittal view is formed by the long axis of the impacted canine and the occlusal plane (Fig 2, *B*).
4. Lateral incisor inclination to the maxillary plane, where the angle in the sagittal view is formed by the long axis of the lateral incisor and the maxillary plane (Fig 2, *C*).

Statistical analysis

Analyses were performed on data from subjects with unilateral impaction. The aim of this study was to predict whether a canine would be impacted, not whether a patient had an impacted canine. Therefore, in the statistical

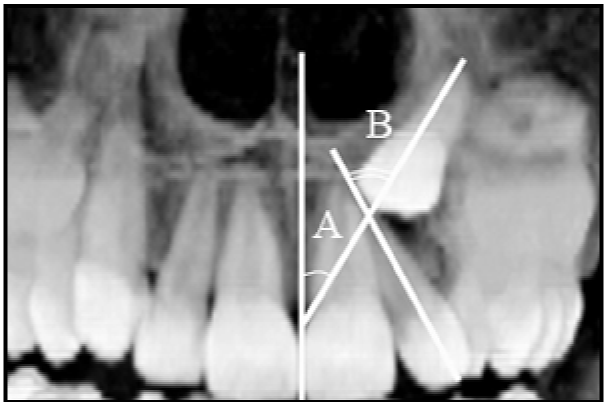

Fig 3. Coronal view of CBCT image illustrating the reference lines of the angular measurements: *A*, canine angulation to the midline; *B*, canine angulation to the lateral incisor.

analysis, independent instead of dependent tests were used; Fisher exact tests and Mann-Whitney U tests were used to compare scores and measurements between impacted and nonimpacted canines from patients with unilateral impaction. The area under the receiver operating curve (AUC) was reported for each score and measurement to quantify the discriminative ability (0.5 = random prediction, 1 = perfect discrimination). The reliability of the measurements was assessed using the records of 12 randomly selected patients and having the same investigator (A.A.) repeat the linear and angular measurements. The systematic error was evaluated with the intraclass correlation coef cient (ICC).

From these results, 6 variables were considered for a multivariable model, based on the AUC, clinical considerations, and the correlations among the variables. A backward selection procedure, with 0.157 as the critical level for the *P* value, was applied to obtain a more parsimonious prediction model. This critical value corresponds to the use of the Akaike information criterion (AIC) for model selection. With the AIC, we required the increase in the model's chi-square value to be larger than 2 times the degrees of freedom. A bootstrap resampling procedure was used to verify whether the variables retained in the nal multivariable model are truly independent predictors or, rather, are noise variables.[16] In the applied modeling approach, the same data were used to develop and validate the model. Furthermore, there was a clear risk of overfitting, originating from consideration of many predictors compared with the number of impactions and from the application of an automated model selection procedure.[17] The resulting prediction model and its related AUC were therefore overoptimistic, in the sense that the future performance in new patients was overestimated. Therefore, a leave-1-out cross-validation was applied. Also, an optimism-corrected estimate of the performance (AUC) was obtained by a bootstrap resampling procedure. All analyses were performed with SAS software (version 9.2 for Windows; SAS, Cary, NC).

RESULTS

Tables I-III present comparisons of impacted and nonimpacted canines in terms of canine-related variables (scores), linear measurements, and angular measurements, respectively.

Many signi cant and clinically relevant differences were found between impacted and nonimpacted canines. Canine rotation, canine crown position, canine cusp tip to midline and to occlusal plane, canine angle to midline, and canine angle to lateral incisor were considered as variables in a multivariable prediction model for canine impaction.

The results from the multivariable logistic regression model for the 6 preselected predictors are shown in Table IV. The AUC values of the prespecified model for these 6 predictors were 0.964 (95% confidence interval [CI]: 0.934, 0.994) and 0.948 (95% CI: 0.909, 0.986) after cross-validation.

The results from the model obtained after application of a backward selection procedure are given in Table V. The probability of true impaction can be obtained as follows:

$$\exp(\mu)/(1 + \exp(\mu)),$$

where

$$\mu = -5.66 + 2.11^{*}x_{1} + 3.28^{*}x + 0.27^{*}x_{.} + 0.11^{*}x_{1},$$

with $x_1 = 1$ if the canine crown position is buccally oriented and $x_1 = 0$ if not; $x = 1$ if the canine crown position is palatally oriented and $x = 0$ if not; x_1 is the linear measurement from canine cusp tip to the occlusal plane in the sagittal view (in millimeters); and x_1 is the canine angle to the lateral incisor in the coronal view (measured in degrees).

The index of discrimination (AUC) of this final model equals 0.965 (95% CI: 0.936, 0.995). The optimism-corrected estimate of the AUC still equals 0.953. Figure 4 shows the probability of canine impaction for a patient with bilateral impacted canines using the final prediction model.

For most measurements, the reliability ranged from 0.71 to 0.98 as quantified by the ICC; this is acceptable. However, for some measurements (eg, width of canine crown and width of the lateral incisor in millimeters), the ICC was lower than 0.7. The reliability values of the canine cusp tip to the occlusal plane and the canine angle to the lateral incisor in the prediction model were excellent (0.98 and 0.98, respectively).

Table I. Comparison of canine-related variables (scores) in percentages between impacted and nonimpacted canines of 65 subjects with unilateral canine impaction

Variable	*Not impacted (%)*	*Impacted (%)*	*P value**	*AUC (95% CI)*
Crowding				
No crowding	75.3	76.9	NS	0.51 (0.43, 0.58)
Crowding	24.7	23.1		
Deciduous canine				
Missing tooth	78.5	52.3	0.007	0.64 (0.56, 0.72)
No resorption	3	10.8		
Resorbed root	18.5	36.9		
Canine development				
Complete development	75.4	63	NS	0.56 (0.48, 0.64)
3/4 of the root developed	20	30.8		
1/2 of the root developed	4.6	6.2		
Open canine apex				
Closed or dilacerated	41.5	29.2	NS	0.56 (0.48, 0.65)
Open	58.5	70.8		
Abnormality				
No abnormality	78.5	73.8	NS	0.52 (0.45, 0.60)
Abnormality	21.5	26.2		
Rotation				
No rotation	60	24.6	<0.001	0.73 (0.65, 0.81)
Mesiovestibular rotation	16.9	20		
Distovestibular rotation	16.9	20		
Mesiopalatal rotation	3.1	23.1		
Distopalatal rotation	3.1	12.3		
Rotation				
No rotation	60	24.6	<0.001	0.68 (0.60, 0.76)
Rotation	40	75.4		
Canine crown position				
Palatally	4.6	47.7	<0.001	0.85 (0.78, 0.91)
Buccally	20	38.5		
Line of the arch	75.4	13.8		
First premolar				
Single root	21.5	18.5	NS	0.55 (0.46, 0.64)
Separated root	52.3	46.1		
Two roots	26.2	35.4		
Anterior apical area (axial)				
Optimal	50.8	26.2	0.017	0.63 (0.54, 0.72)
Small	32.3	47.7		
Severe	16.9	26.1		
Contact relationship to lateral incisor				
No contact	64.6	13.8	<0.001	0.75 (0.68, 0.83)
Contact	35.4	86.2		
Contact relationship to central incisor				
No contact	100	83.1	<0.001	0.59 (0.54, 0.63)
Contact	0	16.9		
Contact relationship to first premolar				
No contact	98.5	90.8	NS	0.54 (0.50, 0.58)
Contact	1.5	9.2		

Canine rotation and canine crown position with a high AUC index were considered as variables in a multivariable prediction model for canine impaction.
NS, Not significant.
*From Fisher's exact or Mann-Whitney U test, as appropriate.

DISCUSSION

Patients with impacted canines usually endure long treatment times, and successful orthodontic treatment and final treatment outcome of impacted canines are unpredictable.[12] It has been found that treating a malocclusion with an impacted canine takes longer than treating a similar malocclusion without an impaction.[10,11] This could be due to the application of different treatment methods in young patients according to the concept of "watch and wait." The

Table II. Comparison of linear measurements (millimeters) between impacted and nonimpacted canines of 65 subjects with unilateral canine impaction

Variable	*Statistic*	*Not impacted*	*Impacted*	*P value**	*AUC (95% CI)*
Canine cusp tip to midline	Mean (SD)	14.7 (2.6)	10.0 (4.2)	<0.001	0.86 (0.79, 0.93)
	Median (range)	15.2 (5.6-18.5)	9.6 (0.0-24.0)		
Canine cusp tip to occlusal plane	Mean (SD)	3.6 (4.1)	10.6 (4.3)	<0.001	0.88 (0.82, 0.94)
	Median (range)	2.7 (0.0-15.6)	10.6 (0.0-22.5)		
Canine apex to midline	Mean (SD)	12.8 (1.7)	13.9 (2.41)	0.003	0.65 (0.56, 0.75)
	Median (range)	12.5 (9.3-17.0)	13.8 (5.8-19.0)		
Mesiodistal width of canine crown	Mean (SD)	7.6 (0.5)	7.8 (0.5)	NS	0.60 (0.50, 0.69)
	Median (range)	7.6 (6.6-8.6)	7.8 (6.7-8.9)		
Buccolingual width of canine crown	Mean (SD)	8.0 (0.6)	8.1 (0.5)	NS	0.55 (0.45, 0.65)
	Median (range)	7.9 (6.9-9.2)	7.9 (7.4-9.2)		
Mesiodistal width of the lateral incisor	Mean (SD)	6.3 (0.7)	6.4 (0.8)	NS	0.57 (0.47, 0.67)
	Median (range)	6.3 (4.2-8.5)	6.4 (3.9-9.1)		
Buccolingual width of the lateral incisor	Mean (SD)	6.4 (0.8)	6.4 (0.6)	NS	0.50 (0.50, 0.50)
	Median (range)	6.4 (3.1-7.9)	6.4 (4.3-7.8)		
Length of the lateral incisor	Mean (SD)	21.8 (2.5)	21.0 (3.2)	NS	0.59 (0.49, 0.69)
	Median (range)	22.2 (13.6-26.7)	21.4 (12.9-27.9)		
Mesiodistal space at occlusal level	Mean (SD)	7.0 (1.9)	5.0 (2.9)	<0.001	0.74 (0.66, 0.83)
	Median (range)	7.4 (0.8-12.1)	5.8 (0.0-11.4)		
Mesiodistal space at apex level	Mean (SD)	9.1 (1.9)	8.0 (2.5)	0.005	0.64 (0.55, 0.74)
	Median (range)	8.9 (3.2-13.2)	7.6 (2.9-13.4)		

Canine cusp tip to midline and canine cusp tip to occlusal plane with a high AUC index were considered as variables in a multivariable prediction model for canine impaction.
NS, Not significant.
*From Mann-Whitney U test.

Table III. Comparison of angular measurements between impacted and nonimpacted canines of 65 subjects with unilateral canine impaction

Variable	*Statistic*	*Not impacted*	*Impacted*	*P value**	*AUC (95% CI)*
Canine angle to midline, coronal view	Mean (SD)	8.8 (6.5)	20.7 (14.9)	<0.001	0.77 (0.69, 0.85)
	Median (range)	6.9 (0.6-29.7)	17.0 (1.1-62.7)		
Canine angle to the lateral incisor, coronal view	Mean (SD)	10.5 (8.5)	36.3 (18.1)	<0.001	0.90 (0.85, 0.95)
	Median (range)	8.0 (1.2-38.9)	38.0 (5.7-71.8)		
Canine angle to the occlusal plane, sagittal view	Mean (SD)	63.0 (12.52)	52.9 (17.19)	<0.001	0.69 (0.59, 0.78)
	Median (range)	65.4 (18.7-86.3)	54.6 (1.3-82.8)		
Lateral incisor inclination to the maxillary plane, sagittal view	Mean (SD)	106.4 (14.5)	104.2 (18.9)	NS	0.56 (0.45, 0.66)
	Median (range)	108.0 (11.8-126.9)	105.8 (9.3-139.0)		

The canine angle to midline and canine angle to lateral incisor with a high AUC index were considered as variables in a multivariable prediction model for canine impaction.
NS, Not significant.
*From Mann-Whitney U test.

second reason could be a lack of de ned impaction. The most important factor before treatment is the con rmation of a true impaction rather than a normal delay in eruption. The latter usually responds positively to any treatment applied. Therefore, identifying an impaction is essential, requiring an understanding of the differences between impacted and nonimpacted canines in relation to adjacent structures.

The position of impacted canines in the dental arch, canine development, possible overlap with the roots of adjacent incisors, root resorption and anomalies, and linear and angular measurements on radiographs are frequently used as variables for radiologic assessment and have been discussed as predictors of canine eruption.[16,11,16-19] Dental development could be a predictor of a palatally impacted canine.[11] In a 2D study, if the canine is completely developed, the canine angle to the midline and the overlap with the lateral incisor are considered good indicators of canine impaction.[20] Radiographic parameters have also been correlated in the mixed dentition as predictors of the probability of spontaneous eruption or the success rate of the interceptive treatment outcome of the displaced permanent canine.[17,16,21,11,19] Ericson and Kurol[17] reported that

Table IV. Results from multivariable logistic regression model with 6 preselected predictors (AUC of this model equals 0.964 [95% CI: 0.934, 0.994])

Parameter	*Estimate*	*Odds ratio (95% CI)*	*P value*	*BIF (%)*
Intercept	−5.13			
Rotation	0.14	1.15 (0.28, 4.71)	0.8501	13
Canine crown position			0.0110	92
Buccal	2.07	7.90 (1.60, 39.03)	0.0113	
Palatal	3.04	20.82 (1.92, 225.86)	0.0126	
Line of the arch	*			
Canine cusp tip to midline (mm), axial view	−0.04	0.97 (0.74, 1.25)	0.7905	23
Canine cusp tip to occlusal (mm), sagittal view	0.26	1.29 (1.10, 1.52)	0.0023	97
Canine angle (°) to midline, coronal view	0.01	1.01 (0.91, 1.12)	0.8940	9
Canine angle (°) to the lateral incisor, coronal view	0.11	1.11 (1.04, 1.19)	0.0037	98

Canine crown position, canine cusp tip to occlusal on sagittal view, and canine angle to the lateral incisor on coronal view were used in the final prediction model because they have a high BIF (%) and did not have high correlation with other variables in the model.
BIF, Bootstrap importance frequency: ie, the percentage of bootstrap samples in which the variable is retained in the final model after application of the backward selection procedure.
*Reference category.

Table V. Results from the final prediction model (obtained after application of a backward selection procedure with 0.157 as the critical level for a *P* value to remain in the model)

Variable	*Estimate*	*Odds ratio (95% CI)*	*P value*
Intercept	−5.66		
Canine crown position			0.0014
Buccally	2.11	8.26 (1.77, 38.52)	0.0072
Palatally	3.28	26.45 (3.90, 179.51)	0.0008
Line of the arch	*		
Canine cusp tip to occlusal (mm) on sagittal view	0.27	1.31 (1.12, 1.52)	0.0006
Canine angle (°) to the lateral incisor on coronal view	0.11	1.12 (1.04, 1.19)	0.0014

AUC = 0.965 (95% CI: 0.936, 0.995).
The probability of true impaction = exp(μ)/(1 + exp(μ)), where $\mu = -5.66 + 2.11{*}x_1 + 3.28{*}x_2 + 0.27{*}x_3 + 0.11{*}x_4$ with $x_1 = 1$ if the canine crown position is buccally oriented and $x_1 = 0$ if not; $x_2 = 1$ if the canine crown position is palatally oriented and $x_2 = 0$ if not; x_3 is the linear measurements from canine cusp tip to the occlusal aspect in the sagittal view (millimeters); and x_4 is the canine angle (degrees) to the lateral incisor in the coronal view (degrees).
*Reference category.

the degree of mesial overlap of the maxillary canine relative to the adjacent lateral incisor plays a role in the severity of impaction and the probability of spontaneous eruption. Warford et al[11] found that the degree of canine mesial overlap with an adjacent lateral incisor is a better predictor of impaction than angulations. Power and Short[15] found that if canine angulation is more than 31° to the midline, the chances of eruption after deciduous extraction are decreased. However, the position of impacted canines, linear measurements, and their angulations have been found by some authors to be invalid as indicators of the successful outcome of interceptive orthodontic treatment, length of treatment, and periodontal status.[33-41,43-44] Sajnani and King[44] found that beyond the age of 9 years, a statistical difference for canine cusp tip to the occlusal maxillary plane was the most important predictor of impaction, more than all other measurements on panoramic radiographs. In our study, canine crown position was used in the model as a predictor and was not correlated to the specific factors to differentiate between either palatal or buccal position. We aimed to identify impaction vs nonimpaction, regardless of the location. We selected only subjects with unilateral impaction to avoid patient variations and misdiagnoses of impaction in bilateral patients.

In addition to the contradictory results of previous studies, those studies used 2D images and tested only 1 or 2 variables for canine impaction. Furthermore, those studies showed the significant relationship between impacted canines and radiographic factors to spontaneous eruption or the success rate of interceptive treatment without taking into account the correlations between variables. Moreover, they failed to verify whether the canines were truly impacted and whether those factors were independent predictors or whether there was an interaction between them. In this study, unilaterally impacted canines were selected and were determined to be truly impacted because the contralateral side was erupted, and the ipsilateral side of all patients showed no improvement in position after a follow-up of 1 year. However, the sample was considered to represent impacted canines regardless of whether the impaction was unilateral or bilateral. Likewise, the

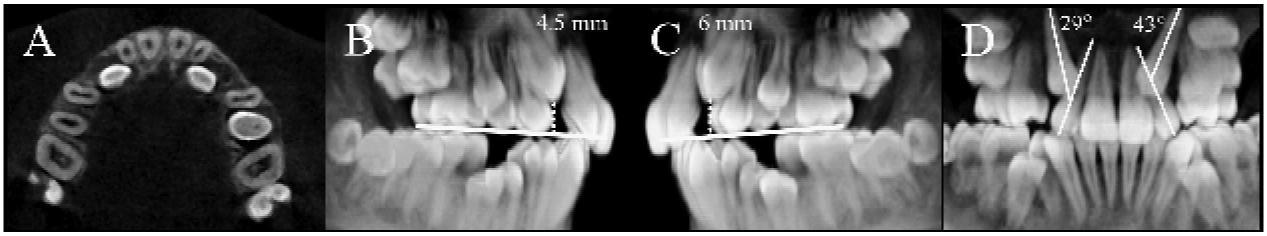

Fig 4. An example of the prediction model of impaction for a 14-year-old girl with bilateral impacted canines illustrating the probability of maxillary canine impaction: **A,** canine crown positions of the canines were palatally located; **B,** cusp of the right canine tip to the occlusal plan (4.5 mm) in the sagittal view; **C,** cusp tip of the left canine to the occlusal plane (6 mm) in the sagittal view; **D,** angles of the right and left canines (29° and 43°, respectively) to the lateral incisor in the coronal view. μ of the right canine= $5.66+2.11*0+3.28*1+0.27*4.5+0.11*29=2.03$. The probability of impaction of the right canine $=\exp(2.03)/(1+\exp(2.03))=88\%$. μ of the left canine= $5.66+2.11*0+3.28*1+0.27*6+0.11*43=3.97$. The probability of impaction of the left canine $=\exp(3.97)/1+\exp(3.97)=98\%$.

nonimpacted canines were considered to represent nonimpacted canines, whether the patient had a unilateral impaction or not.

Compared with conventional 2D images, CBCT images provide applicable diagnostic information for dental structures in the sagittal, axial, and coronal planes without overlap, as well as giving invaluable information related to impacted canines.[15,16] Our previous studies highlighted that more information is gained from CBCT than from panoramic images.[10,17] A CBCT evaluation of the impacted canine improved the position assessment relative to adjacent teeth, providing a greater degree of confidence in the treatment plan than with 2D images.[16,19]

Several significant differences were found between impacted and nonimpacted canines. Since the number of variables was high compared with the sample size, a selection of variables was made for constructing a multivariable prediction model (Table IV). This selection of variables was based on the fact that these variables were clinically relevant with a high AUC index and did not have a high correlation with other variables in the model. In this study, contact relationships, the mesiodistal spaces for the impacted canine at the occlusal level, and the mesiodistal spaces available for the impacted canine at the apical thirds were significantly different between impacted and nonimpacted canines. However, those variables were not used in the selective predictors because the AUC indexes were low (0.76, 0.74, and 0.64, respectively). A lack of mesiodistal space is the main cause of buccally impacted canines, whereas excessive space is correlated with palatally impacted canines.[7,8] In a CBCT study, it was reported that the root length and buccolingual and mesiodistal crown widths of the lateral incisors were smaller in a sample of palatally impacted canines.[20] Furthermore, there is sexual dimorphism in mesiodistal crown widths between male and female patients.[21] Our samples included all kinds of impaction (buccal, palatal, and line of arch). Therefore, no difference was found between impacted and nonimpacted canines in lengths or crown widths of the lateral incisors, consistent with results from a CBCT study of unilaterally impacted canines.[20] CBCT was found to be precise in measurements of root length, with a high level of reproducibility.[21] The linear and angular measurements in the CBCT images were found to be accurate in subjects with canine impaction.[21]

The canine-to-lateral-incisor angle, rather than the lateral incisor inclination, has been found to have a direct influence on canine impaction when CBCT was used.[22] This agrees with our findings. Incisor inclinations (labial root torque) in Angle Class II Division 2 patients have been found to be risk factors for palatally impacted canines.[5,6] However, in another study, incisor inclination in patients with buccally impacted canines showed no significant relationship.[5] We found no signi cant difference between impacted and nonimpacted canines in lateral incisor inclinations to the maxillary plane.

We found no straightforward formula in the literature for the prediction of canine impactions based on CBCT. No guidance for the use of CBCT radiographs has been established to identify impaction for the development of proper treatment plans. Therefore, this study was carried out to identify impactions based on the prediction formula in CBCT images in patients with unilaterally impacted maxillary canines. In this study, the analysis of CBCT images generated a number of radiographic factors. These significant differences between impacted and nonimpacted canines are useful in the understanding of impaction and the patterns of eruption, and the prediction of canine impaction. With the methodology applied, we attempted to differentiate impaction vs nonimpaction using the prediction model with a high AUC value of 0.965, ranging from 0.936 to 0.995. Since the selection of the 6 predictors was based on the data presented, predictions obtained from the final multivariable model were expected to be too extreme, and the AUC obtained after internal validation is still likely to be overoptimistic.

The limitation of this study was the small sample size that was not determined based on a power analysis. This was because our aim was not only to find significant differences, but also to develop a prediction model with practical relevance. Hence, this study was set up for testing most of the radiographic parameters in the literature, and the interest focused on large differences, not only statistically significant ones. Thus, the study was not powered to detect subtle differences. External validation is necessary to evaluate the true performance of this model in a new setting. It is of crucial importance to establish an easily validated method to predict canine impaction in young patients to help orthodontists identify the probability of impaction for the optimal timing of intervention. It is essential to test the reliability and the reproducibility of this method. Further studies are needed to validate the prediction model on different populations prospectively.

CONCLUSIONS

Prediction of the probability of canine impaction based on CBCT was excellent. The canine angulation to the lateral incisor on the coronal view, the canine cusp tip to the occlusal plane on the sagittal view, and the canine crown position were the strongest predictors based on the CBCT radiographs and may help orthodontists to identify the probability of impaction for optimally timing the intervention.

REFERENCES

1. Celikoglu M, Kamak H, Oktay H. Investigation of transmigrated and impacted maxillary and mandibular canine teeth in an orthodontic patient population. J Oral Maxillofac Surg 2010;68:1001-6.
2. Bishara SE. Impacted maxillary canines: a review. Am J Orthod Dentofacial Orthop 1992;101:159-71.
3. Becker A, Smith P, Behar R. The incidence of anomalous maxillary lateral incisors in relation to palatally-displaced cuspids. Angle Orthod 1981;51:24-9.
4. Oliver RG, Mannion JE, Robinson JM. Morphology of the maxillary lateral incisor in cases of unilateral impaction of the maxillary canine. Br J Orthod 1989;16:9-16.
5. Cernochova P, Izakovicova-Holla L. Dentoskeletal characteristics in patients with palatally and buccally displaced maxillary permanent canines. Eur J Orthod 2012;34:754-61.
6. Ludicke G, Harzer W, Tausche E. Incisor inclination—risk factor for palatally-impacted canines. J Orofac Orthop 2008;69:357-64.
7. Jacoby H. The etiology of maxillary canine impactions. Am J Orthod 1983;84:125-32.
8. Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. Angle Orthod 1994;64:249-56.
9. Al-Nimri K, Gharaibeh T. Space conditions and dental and occlusal features in patients with palatally impacted maxillary canines: an aetiological study. Eur J Orthod 2005;27:461-5.
10. Anic-Milosevic S, Varga S, Mestrovic S, Lapter-Varga M, Slaj M. Dental and occlusal features in patients with palatally displaced maxillary canines. Eur J Orthod 2009;31:367-73.
11. Ericson S, Kurol J. Radiographic assessment of maxillary canine eruption in children with clinical signs of eruption disturbance. Eur J Orthod 1986;8:133-40.
12. Rimes RJ, Mitchell CN, Willmot DR. Maxillary incisor root resorption in relation to the ectopic canine: a review of 26 patients. Eur J Orthod 1997;19:79-84.
13. Yan B, Sun Z, Fields H, Wang L. Maxillary canine impaction increases root resorption risk of adjacent teeth: a problem of physical proximity. Am J Orthod Dentofacial Orthop 2012;142:750-7.
14. Lai CS, Bornstein MM, Mock L, Heuberger BM, Dietrich T, Katsaros C. Impacted maxillary canines and root resorptions of neighbouring teeth: a radiographic analysis using cone-beam computed tomography. Eur J Orthod 2013;35:529-38.
15. Alqerban A, Jacobs R, Lambrechts P, Loozen G, Willems G. Root resorption of the maxillary lateral incisor caused by impacted canine: a literature review. Clin Oral Investig 2009;13:247-55.
16. Stewart JA, Heo G, Glover KE, Williamson PC, Lam EW, Major PW. Factors that relate to treatment duration for patients with palatally impacted maxillary canines. Am J Orthod Dentofacial Orthop 2001;119:216-25.
17. Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. Eur J Orthod 1988;10:283-95.
18. Power SM, Short MB. An investigation into the response of palatally displaced canines to the removal of deciduous canines and an assessment of factors contributing to favourable eruption. Br J Orthod 1993;20:215-23.
19. Baccetti T, Leonardi M, Armi P. A randomized clinical study of two interceptive approaches to palatally displaced canines. Eur J Orthod 2008;30:381-5.
20. Baccetti T, Sigler LM, McNamara JA Jr. An RCT on treatment of palatally displaced canines with RME and/or a transpalatal arch. Eur J Orthod 2011;33:601-7.
21. Alessandri BG, Zanarini M, Incerti PS, Marini I, Gatto MR. Preventive treatment of ectopically erupting maxillary permanent canines by extraction of deciduous canines and first molars: a randomized clinical trial. Am J Orthod Dentofacial Orthop 2011;139:316-23.
22. Leonardi M, Armi P, Franchi L, Baccetti T. Two interceptive approaches to palatally displaced canines: a prospective longitudinal study. Angle Orthod 2004;74:581-6.
23. Caminiti MF, Sandor GK, Giambattistini C, Tompson B. Outcomes of the surgical exposure, bonding and eruption of 82 impacted maxillary canines. J Can Dent Assoc 1998;64:572-9.
24. Becker A, Chaushu S. Success rate and duration of orthodontic treatment for adult patients with palatally impacted maxillary canines. Am J Orthod Dentofacial Orthop 2003;124:509-14.
25. Zuccati G, Ghobadlu J, Nieri M, Clauser C. Factors associated with the duration of forced eruption of impacted maxillary canines: a retrospective study. Am J Orthod Dentofacial Orthop 2006;130:349-56.
26. Nieri M, Crescini A, Rotundo R, Baccetti T, Cortellini P, Pini Prato GP. Factors affecting the clinical approach to impacted maxillary canines: a Bayesian network analysis. Am J Orthod Dentofacial Orthop 2010;137:755-62.

27. Kau CH, Pan P, Gallerano RL, English JD. A novel 3D classification system for canine impactions—the KPG index. Int J Med Robot 2009;5:291-6.
28. Dalessandri D, Migliorati M, Rubiano R, Visconti L, Contardo L, Di Lenarda R, et al. Reliability of a novel CBCT-based 3D classification system for maxillary canine impactions in orthodontics: the KPG index. ScientificWorldJournal 2013;2013:921234.
29. San Martin DE, English JD, Kau CH, Gallerano RL, McGrory KR, Salas AM, et al. The KPG index—a novel 3D classification system for maxillary canine impactions. Tex Dent J 2012;129:265-74.
30. Alqerban A, Jacobs R, Fieuws S, Willems G. Comparison of two cone beam computed tomographic systems versus panoramic imaging for localization of impacted maxillary canines and detection of root resorption. Eur J Orthod 2011;33:93-102.
31. Warford JH Jr, Grandhi RK, Tira DE. Prediction of maxillary canine impaction using sectors and angular measurement. Am J Orthod Dentofacial Orthop 2003;124:651-5.
32. Fleming PS, Scott P, Heidari N, Dibiase AT. Influence of radiographic position of ectopic canines on the duration of orthodontic treatment. Angle Orthod 2009;79:442-6.
33. Smith B, Stewart K, Liu S, Eckert G, Kula K. Prediction of orthodontic treatment of surgically exposed unilateral maxillary impacted canine patients. Angle Orthod 2012;82:723-31.
34. Sajnani AK, King NM. Early prediction of maxillary canine impaction from panoramic radiographs. Am J Orthod Dentofacial Orthop 2012;142:45-51.
35. Ericson S, Bjerklin K, Falahat B. Does the canine dental follicle cause resorption of permanent incisor roots? A computed tomographic study of erupting maxillary canines. Angle Orthod 2002;72:95-104.
36. Austin PC, Tu JV. Bootstrap methods for developing predictive models. Am Statistician 2004;58:131-7.
37. Steyerberg EW. Clinical prediction models: a practical approach to development, validation, and updating. New York: Springer; 2009.
38. Ericson S, Kurol J. Radiographic examination of ectopically erupting maxillary canines. Am J Orthod Dentofacial Orthop 1987;91:483-92.
39. Ericson S, Kurol J. Resorption of maxillary lateral incisors caused by ectopic eruption of the canines. A clinical and radiographic analysis of predisposing factors. Am J Orthod Dentofacial Orthop 1988;94:503-13.
40. Stivaros N, Mandall NA. Radiographic factors affecting the management of impacted upper permanent canines. J Orthod 2000;27:169-73.
41. Becker A, Chaushu S. Dental age in maxillary canine ectopia. Am J Orthod Dentofacial Orthop 2000;117:657-62.
42. Grande T, Stolze A, Goldbecher H, Kahl-Nieke B. The displaced maxillary canine—a retrospective study. J Orofac Orthop 2006;67:441-9.
43. Crescini A, Nieri M, Buti J, Baccetti T, Pini Prato GP. Pre-treatment radiographic features for the periodontal prognosis of treated impacted canines. J Clin Periodontol 2007;34:581-7.
44. Sajnani AK, King NM. The sequential hypothesis of impaction of maxillary canine—a hypothesis based on clinical and radiographic findings. J Craniomaxillofac Surg 2012;40:e375-85.
45. Liu DG, Zhang WL, Zhang ZY, Wu YT, Ma XC. Localization of impacted maxillary canines and observation of adjacent incisor resorption with cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:91-8.
46. Walker L, Enciso R, Mah J. Three-dimensional localization of maxillary canines with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2005;128:418-23.
47. Alqerban A, Jacobs R, Souza PC, Willems G. In-vitro comparison of 2 cone-beam computed tomography systems and panoramic imaging for detecting simulated canine impaction-induced external root resorption in maxillary lateral incisors. Am J Orthod Dentofacial Orthop 2009;136:764.e1-11.
48. Alqerban A, Hedesiu M, Baciut M, Nackaerts O, Jacobs R, Fieuws S, et al. Pre-surgical treatment planning of maxillary canine impactions using panoramic vs cone beam CT imaging. Dentomaxillofac Radiol 2013;42:20130157.
49. Alqerban A, Willems G, Bernaerts C, Vangastel J, Politis C, Jacobs R. Orthodontic treatment planning for impacted maxillary canines using conventional records versus 3D CBCT. Eur J Orthod 2014;36:698-707.
50. Liuk IW, Olive RJ, Griffin M, Monsour P. Maxillary lateral incisor morphology and palatally displaced canines: a case-controlled cone-beam volumetric tomography study. Am J Orthod Dentofacial Orthop 2013;143:522-6.
51. Chaushu S, Sharabi S, Becker A. Tooth size in dentitions with buccal canine ectopia. Eur J Orthod 2003;25:485-91.
52. Yan B, Sun Z, Fields H, Wang L, Luo L. Etiologic factors for buccal and palatal maxillary canine impaction: a perspective based on cone-beam computed tomography analyses. Am J Orthod Dentofacial Orthop 2013;143:527-34.
53. Lund H, Gröndahl K, Gröndahl HG. Cone beam computed tomography for assessment of root length and marginal bone level during orthodontic treatment. Angle Orthod 2010;80:466-73.
54. Naoumova J, Kjellberg H, Palm R. Cone-beam computed tomography for assessment of palatal displaced canine position: a methodological study. Angle Orthod 2014;84:459-66.
55. Baratieri C, Canongia AC, Bolognese AM. Relationship between maxillary canine intra-alveolar position and maxillary incisor angulation: a cone beam computed tomography study. Braz Dent J 2011;22:146-50.

ORIGINAL ARTICLE CE AJO-DO

Early prediction of maxillary canine impaction from panoramic radiographs

Anand K. Sajnani[a] and Nigel M. King[b]
Navi Mumbai, India, and Hong Kong SAR, China

Introduction: Treatment of impacted maxillary canines frequently requires surgical intervention, which can involve substantial complications. Thus, it is desirable to identify a reliable method for the early diagnosis of canine displacement. In this study, we sought to determine whether impaction of a maxillary canine can be predicted using measurements made on a panoramic radiograph. **Methods:** This retrospective study was conducted at a dental hospital in Hong Kong with panoramic radiographs. Geometric measurements were made on 384 panoramic radiographs of patients with a unilaterally impacted maxillary canine (group I) to characterize its presentation and compare them with the unaffected antimere (group II). **Results:** There was a clinically discernible difference of 4 mm at the age of 8 years and beyond between the mean distance of the tip of the impacted canine (group I) and that of the antimere (group II) from the occlusal plane ($P < 0.05$). Furthermore, there was a statistically significant difference at the age of 9 years and beyond between the 2 groups according to the position in different sectors and according to the mean angle made with the midline ($P < 0.05$). **Conclusions:** Diagnosis of maxillary canine impaction is possible at 8 years of age by using geometric measurements on panoramic radiographs. (Am J Orthod Dentofacial Orthop 2012;142:45-51)

The fundamental aspect in the diagnosis of and treatment planning for an impacted maxillary permanent canine is the ability to recognize and predict its subsequent failure of eruption. Early diagnosis of canine displacement, in relation to the surrounding structures, is based primarily on a radiographic examination. Ericson and Kurol,[1] who studied children aged 10 to 13 years, proposed that the diagnosis could be made using a panoramic film and that the time could be defined as "moderately" early. They used a series of geometric measurements made on panoramic radiographs that included the angle formed by the long axis of the canine with the midline, the vertical distance from the tip of the canine to the occlusal plane, and the distribution of the canine into different sectors depending on its location in relation to adjacent teeth. Furthermore, their final observations included the therapeutic effects of an interceptive approach such as extraction of a deciduous canine.[1,2] Lindauer et al[3] used a control group to develop a method to predict canine impaction at an accuracy of 78% with a modification of the procedure originally proposed by Ericson and Kurol.[1] Overlapping of the lateral incisor by the canine on panoramic radiographs, when development of the incisor has been completed, can be considered a sign of a possible eruptive anomaly of the canine.[1] Likewise, it has been shown that sector location is a significantly better predictor of impaction than tooth angulation.[5] However, the relative diagnostic importance of these radiographic factors, including angulation of the canine to the midline, height from the occlusal plane, and buccopalatal position, has not been previously evaluated in Chinese children and adolescents.

Treatment of a palatally impacted canine usually involves surgical exposure and traction to move the tooth into the correct position.[6] These procedures have high success rates but can involve substantial time and financial costs. They also carry risks of gingival recession, bone loss, and detachment of the gingiva around the treated canine.[7] An interceptive treatment option includes extraction of the deciduous canine to prevent final impaction of the permanent successor. However, this method must first prove a positive diagnosis of canine displacement that will otherwise lead to canine impaction. Therefore, it is desirable to identify a method

[a]Senior lecturer, pediatric dentistry, Terna Dental College and Hospital, Navi Mumbai, India.
[b]Professor, pediatric dentistry, Faculty of Dentistry, University of Hong Kong, Hong Kong SAR, China.
The authors report no commercial, proprietary, or financial interest in the products or companies described in this article.
Reprint requests to: Dr. Anand K. Sajnani, Bin Muftah Medical Centre, Paediatric Dentistry, Al Markhiya Street, PO Box 201357, Doha, Qatar; e-mail, aksajnani@gmail.com.
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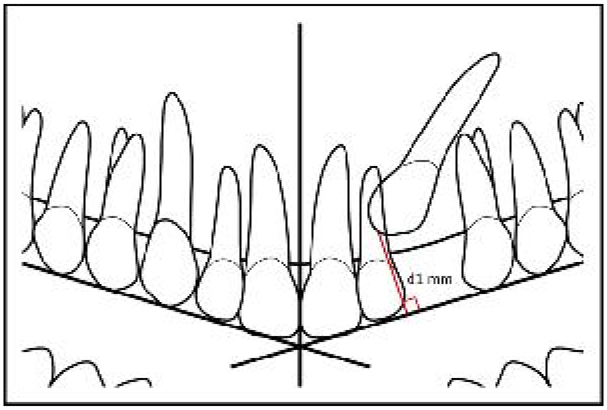

Fig 1. Diagrammatic representation of the measurement of the perpendicular distance from the tip of the impacted canine to the occlusal plane.

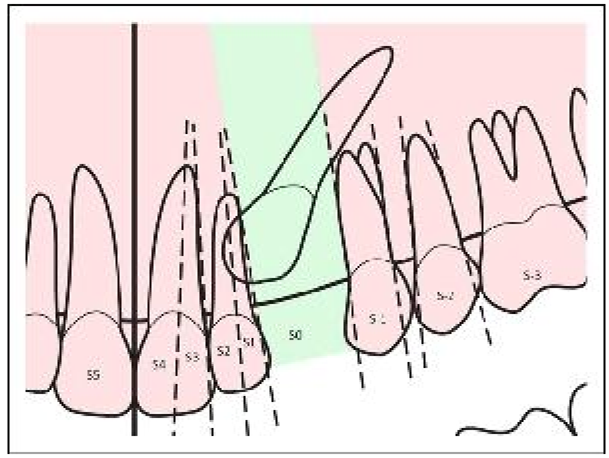

Fig 2. Diagrammatic representation of the distribution of the canine in different sectors depending on the location of the tip of the tooth.

that can give the clinician a reliable protocol for early diagnosis of displacement of a canine and prediction of subsequent impaction.

A panoramic radiograph is a primary routine investigation for many patients. Hence, the variable, visible on that radiograph, could be used diagnostically to predict the impaction of a maxillary canine. This early diagnosis of an impaction can be used to determine the advantages, disadvantages, success rates, and clinical benefits of any operative technique. Thus, the objective of this study was to determine whether impaction of a maxillary canine can be predicted by using measurements made on a panoramic radiograph.

MATERIAL AND METHODS

A total of 384 panoramic radiographs of 442 nonsyndromic patients known to have unilaterally impacted maxillary canines who had attended the Paediatric Dentistry and Orthodontics Clinic at Prince Philip Dental Hospital in Hong Kong SAR, China, were available for assessment. The clinical records and the radiologic data were used to assess and con rm the position of an impacted maxillary canine. The canine was de ned as impacted if its antimere had completely erupted in the oral cavity, but the unerupted canine showed complete root formation radiographically (Fig 1). The radiographs most commonly used to determine the position of the impacted canine are panoramic radiographs in combination with anterior occlusal films by using the vertical parallax principle[5] and periapical radiographs taken at various horizontal angulations with the horizontal parallax technique.[illegible] After the diagnosis had been con rmed from the clinical records and radiologic data, previous panoramic radiographs, if available, were traced to evaluate the position of the permanent canine of these patients. Thus, by using this mixed-longitudinal study design, the location of a canine was determined at different chronologic ages of a patient. All radiographs were examined in a darkened room by using an illuminated x-ray viewing box. The panoramic radiographs were traced with 0.003-in matte acetate tracing paper and a 0.5-mm HB ne lead pencil. Geometric measurements were made on the panoramic radiographs to show the impacted canine (group I) and to compare them with similar measurements made for the antimere tooth (group II). The measurements included the angulation and position (sector) of the tooth, the distance from the occlusal plane, and the stage of root development (adapted from Ericson and Kurol[1]).

The occlusal plane was determined by drawing a horizontal line passing through the incisal edge of the central permanent incisor and the occlusal plane of the first permanent molar on the given side. When the central permanent incisor or the first permanent molar was absent, the lateral permanent incisor or the second permanent molar was used to determine the occlusal plane. In the deciduous dentition stage, the central incisor and the second molar were used to define the occlusal plane. A perpendicular line was then drawn from the incisal tip of the impacted canine and the antimere to the occlusal plane. This distance was called "d1" for the impacted canine group (group I) and "d0" for the antimere group (group II) (Fig 1).

Groups I and II were categorized into different sectors depending on the location of the tip of the tooth in relation to the adjacent teeth (Fig 2).

The angle formed by the long axis of the impacted maxillary canine (group I) with the midline was called "α," and the angle formed by the long axis of the maxillary canine on the antimere side (group II) was called

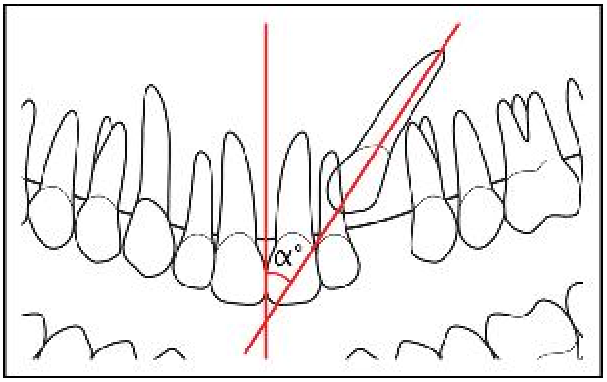

Fig 3. Diagrammatic representation of the measurement of the angle made by the long axis of the impacted canine with the midline.

"θ" (Fig 3). The midline was defined by the following landmarks on the radiograph: intermaxillary suture, anterior nasal spine, nasal septum, and internasal suture. When the tip of the canine was pointing in a direction opposite to the midline, a "−ve" sign was assigned as a pre x.

The root development of the canine was divided into 6 stages. The various stages and their interpretations were stage 0, root formation not yet begun; stage 1, root formation less than a quarter complete; stage 2, root formation between a quarter and a half complete; stage 3, root formation between a half and three quarters complete; stage 4, root formation more than three quarters complete; and stage 5, root formation complete.

All data were input into an Excel worksheet (version 2007; Microsoft, Redmond, Wash), and the data were printed out and checked for any keying-in errors. To determine whether there were any statistical differences between the geometric measurements made on the panoramic radiographs, the paired *t* test was used with the *P* value set at 0.05.

RESULTS

The 384 panoramic radiographs that formed the sample for this study included parts of records from 111 patients with a total of 222 longitudinal follow-up radiographs. The data obtained from all 384 panoramic radiographs were divided into different age groups (Table I) to facilitate comparing the position of the impacted canine (group I) with the unaffected antimere (group II). This included 54 radiographs from patients in the age group of 3 to 8 years. No statistically significant difference was found between the values and measurements obtained for patients in whom the canines were buccally impacted and those in whom the canines were palatally impacted. Hence, the data were combined and the results further analyzed.

There was a statistically significant difference at the age of 5 years between the mean distance of the tip of the impacted canine (group I) and the unaffected antimere (group II) ($P = 0.01$). All age groups beyond the age of 5 years also showed a highly statistically significant difference between the mean location of the impacted canine and the unaffected antimere (Table II).

Table I. Distribution by age of the 384 panoramic radiographs with unilaterally impacted canines

Age of the patient (y)	*Radiographs available (n)*	*Follow-up radiographs available (n)*
3	1	0
4	4	0
5	7	0
6	7	0
7	18	3
8	17	11
9	32	20
10	42	28
11	70	47
12	91	62
13	60	43
14	17	4
15	6	2
16	4	0
17	2	0
18	2	1
19	3	1
21	1	0

Table II. Mean differences between the distance (in millimeters) of the cuspal tip of the impacted canine and the unaffected antimere from the occlusal plane

Age of patients (y)	*Mean distance of impacted canine from occlusal plane (d1)*	*Mean distance of unaffected antimere from occlusal plane (d0)*	*Mean difference between groups (d1-d0)*	P *value*
≤4	19.6	19	0.6	0.3
5	21.9	20.4	1.4	0.01*
6	21	20.3	0.7	0.04*
7	20.4	18.1	2.3	0.04*
8	20.2	16.5	3.7	0.001*
9	19	11.2	7.8	<0.0001*
10	19.7	7	12.7	<0.0001*
11	17.9	3.6	14.3	<0.0001*
12	18.6	2.2	16.4	<0.0001*
13	17.7	1.4	16.3	<0.0001*
14	18.5	1.9	16.6	<0.0001*
≥15	15.7	1.3	14.4	<0.0001*

*Statistically significant.

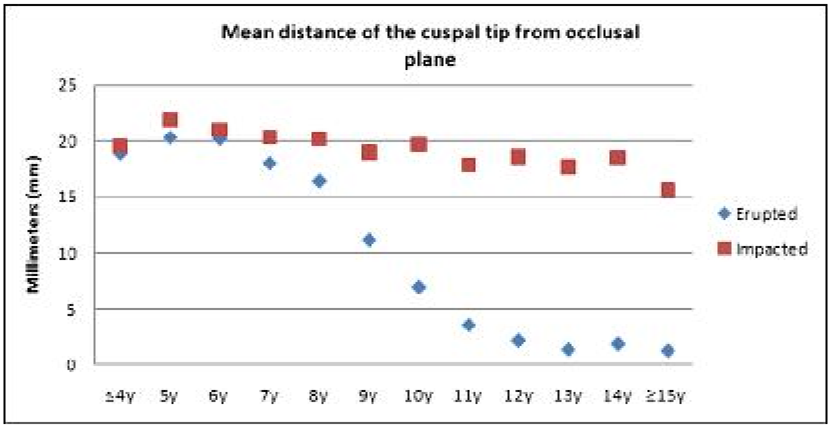

Fig 4. Difference between the mean distances of the cuspal tip of the impacted canine and the unaffected antimere from the occlusal plane according to the age of the patients.

The mean distance covered by the impacted canine in the vertical direction from 5 to 12 years of age was 3.3 mm. During the same period, the mean distance covered by the unaffected antimere was 18.2 mm (Fig 4).

There was a statistically significant difference at the age of 9 years between the mean location of the impacted maxillary canine (group I) and the unaffected antimere (group II) according to the position in the sector ($P = 0.007$) (Table III). All age groups beyond the age of 9 years showed a highly statistically significant difference between the mean location of the impacted canine and the unaffected antimere ($P < 0.0001$). The results demonstrated that, at the age of 9 years, the cusp tip of the impacted canine crosses the distal border of the lateral incisor to lie between the distal border and the midline of the lateral incisor (Fig 5).

There was a highly statistically signi cant difference at the age of 9 years between the mean angle made by the long axis of the impacted canine (group I) with the midline and the angle of the unaffected antimere (group II) with the midline ($P = 0.0004$) (Table IV). All age groups beyond the age of 9 years also showed a highly statistically signi cant difference between the location of the impacted canine and the unaffected antimere ($P < 0.0001$). At 9 years of age, the mean angulation formed by the long axis of the impacted canine with the midline was 28.4°; after that, it continuously increased as the age of the patient increased (Fig 6).

No statistically signi cant difference was obtained between the mean root formation stages of the impacted canine (group I) and the unaffected antimere (group II) in any age group (Table V; Fig 7).

DISCUSSION

Panoramic lms have been used extensively for the identification of diagnostic parameters aimed at facilitating interceptive treatment planning. Occasionally, patients have distortions in the frontal dentoalveolar regions.[1,10] However, it has been demonstrated by mathematical calculations and confirmed by experimental tests that panoramic radiographic images can be reliable for geometric measurements in clinical practice.[11,12] Linear vertical measurements, ratio calculations, and angular measurements can be made on a panoramic radiograph with consistent accuracy.[11] Moreover, a panoramic radiograph is a reliable indicator for determining the buccopalatal position of unerupted maxillary canines.[11]

The need for a method to detect impaction of maxillary canines at an early age has been identified in the literature.[1] Hence, although the panoramic radiographs of patients with unilateral impactions

Table III. Mean differences between sector locations of impacted maxillary canines and their unaffected antimeres

Age of patients (y)	*Mean sector location of impacted canine (S)*	*Mean sector location of unaffected antimere (N)*	*Mean difference between the groups (S-N)*	P *value*
≤4	0	0	0	1
5	0	0	0	1
6	0	0	0	1
7	0.3	0.2	0.1	0.5
8	0.6	0.3	0.3	0.3
9	1.0	0.2	0.7	0.007*
10	1.2	0.1	1.1	<0.0001*
11	1.3	0.0	1.3	<0.0001*
12	1.7	0.0	1.7	<0.0001*
13	1.6	0	1.6	<0.0001*
14	2.3	0	2.3	<0.0001*
≥15	2	0	2.0	<0.0001*

*Statistically significant.

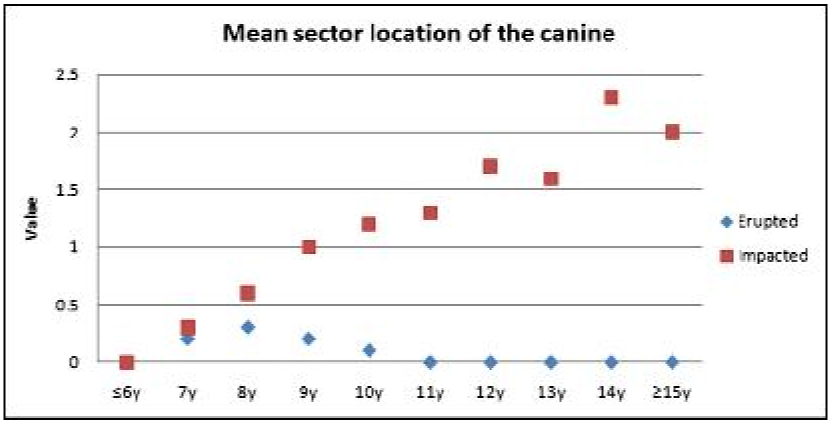

Fig 5. Difference between the mean sector location of the impacted canine and the unaffected antimere according to the age of the patients.

were derived from a mixed-longitudinal study design, they were divided into groups depending on the patients' ages to detect changes in the position of the impacted canine and the unaffected antimere. This would allow determination of the geometric variables and measurements that show a significant change at a given age between the 2 groups and can thus help to predict an impaction early.

There was a significant difference between the 2 groups at the age of 5 years and beyond, when the distance from the cusp tip of the canine to the occlusal plane was used to determine the position of the tooth. Although this difference was small and is clinically difficult to discern, it suggests that the canine that would eventually remain impacted (unerupted) loses the potential for movement in the vertical plane as early as 5 years of age. Thus, it is possible that genetic disturbances start affecting the canine at an early age.[15] Also, it is highly unlikely that the lateral incisor would influence the movement of the canine at this early age, as suggested by the guidance theory.[15,16] However, the antimere canine (unaffected, erupted canine) continued to move downward in the vertical plane and travelled almost 18.2 mm from 5 to 12 years of age; this finding has also been demonstrated by Coulter and Richardson.[17] By 8 years of age, there was a mean difference of approximately 4 mm between the 2 groups that can be detected clinically.

There was a highly statistically significant difference between the 2 groups at the age of 9 years and beyond, when sector location of the cusp tip was used to determine the position of the tooth. At this age, the cusp tip of the impacted canine was found to lie between the distal root surface and the central long axis of the adjacent lateral incisor, whereas the cusp tip of the antimere canine lay superior to the deciduous canine. At all ages beyond 9 years, the impacted canine was

Table IV. Mean differences between angulations (in degrees) formed by the long axis of the impacted canine and the unaffected antimere with the midline

Age of patients (y)	*Mean angle formed by impacted canine with midline (α)*	*Mean angle formed by unaffected antimere with midline (θ)*	*Mean difference between the two groups (α-θ)*	P *value*
≤4	0	0	0	1
5	0	0	0	1
6	5.6	0	5.6	0.2
7	14.3	11.3	3	0.5
8	24.2	20.3	3.9	0.7
9	28.4	11.3	17.1	0.0004*
10	26.9	6.0	20.9	<0.0001*
11	37.4	3.5	33.9	<0.0001*
12	36	2.3	33.7	<0.0001*
13	42.7	1	41.7	<0.0001*
14	44.9	1.9	43	<0.0001*
≥15	41.4	0	39.9	<0.0001*

*Statistically significant.

found to continuously move mesially toward the facial midline, whereas the antimere canine occupied the ideal anatomic position and eventually erupted.

Also, there was a highly statistically significant difference between the 2 groups at the age of 9 years and beyond, when the angle made by the central long axis of the canine with the facial midline was used to determine the position of the tooth. At this age, the impacted canine was mesially tilted at an angle of approximately 30°, and the antimere canine was almost vertical with a mean angle of approximately 11°. At all ages beyond 9 years, an impacted canine was found to have a tendency to tilt mesially, thus increasing the angle that it formed with the facial midline. In contrast, the antimere canine tended to lie almost vertically, and finally it erupted into the oral cavity. These

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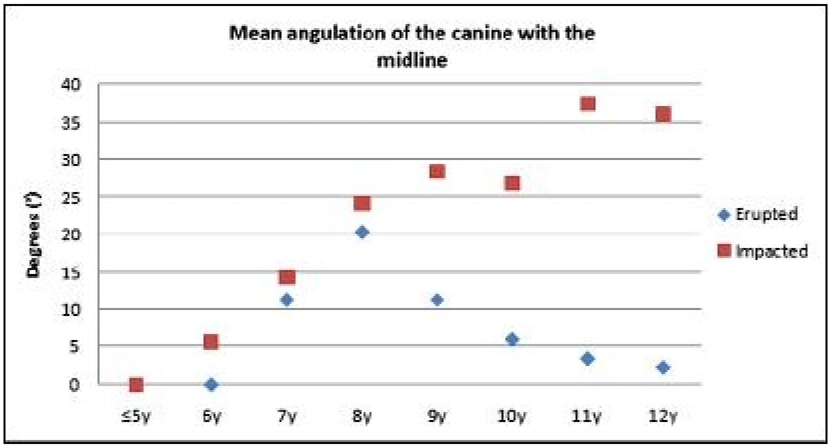

Fig 6. Difference between the mean angulations of the impacted canine and the unaffected antimere with the midline according to the age of the patients.

findings, detectable on a panoramic radiograph, appear to serve as valuable features to help determine the presence of an impacted or potentially ectopically positioned canine for clinical practitioners.

However, the various stages of root formation between an impacted canine and the unaffected antimere failed to show any difference during the entire course of development and eruption of the teeth. This gives rise to the hypothesis that intrinsic mechanisms of development (genetics) do not completely control the position and eventual impaction of the canine[15]; this in turn suggests that other environmental factors, such as guidance from the lateral incisor and crowding, influence the final outcome.[15,16]

Ericson and Kurol[3,4,31] stated that a radiographic examination before the age of 10 years does not provide a reliable means to determine the future unfavorable path of eruption of a maxillary canine. However, our findings suggest that early radiographic examination aided by geometric measurements can provide substantial information on the eruption pattern of a maxillary canine, thus allowing early detection of an impaction.

Warford et al[5] suggested that sector location of the cusp tip of an unerupted canine is the most important predictor of eventual impaction. However, in this study, we demonstrated that the vertical distance from the cusp tip of the unerupted canine to the occlusal plane is the most important and an earlier predictor of eventual impaction than all other measurements made on panoramic radiographs.

Although we drew on a considerable body of data, the material had been collected for clinical purposes, and so the radiographs were often nonsequential; this led to some measurement restrictions. The preponderance of available radiographs in the 11- to 13-year age groups reflects the pattern of referrals to the clinic for treatment. The study design was determined partly by the availability of suitable radiographs, which were taken solely for clinical purposes. Consequently, longitudinal data were available only for some patients. However, the study design also made it possible for the first time to trace and highlight the radiographic position of the maxillary canine in children in the age group of 3 to 8 years.

Table V. Mean differences between root formation stages of the impacted canine and the unaffected antimere

Age of patients (y)	*Mean root formation of impacted canine (Sr)*	*Mean root formation of unaffected antimere (Nr)*	*Difference between the groups (Sr-Nr)*	*P value*
≤6	0	0	0	1
7	1.1	1.1	0	1
8	1.7	1.8	0.1	0.3
9	2.8	2.7	0.1	1.0
10	3.6	3.7	−0.1	0.1
11	4.1	4.1	0.0	0.8
12	4.5	4.6	0.1	0.6
13	4.7	4.7	0.0	0.8
14	4.9	5	−0.1	0.2
≥15	5	5	0.3	0.2

A shortcoming of the radiographic technique used to predict early impaction of the maxillary canine is that it cannot be used to predict bilateral impactions. Also, the geometric measurements obtained from the radiographs of patients with both buccal and palatal impactions were combined, since they produced similar results. It would be useful to perform a study with a similar design but with more radiographs especially in the younger age group (7-10 years) and to compare the results with our

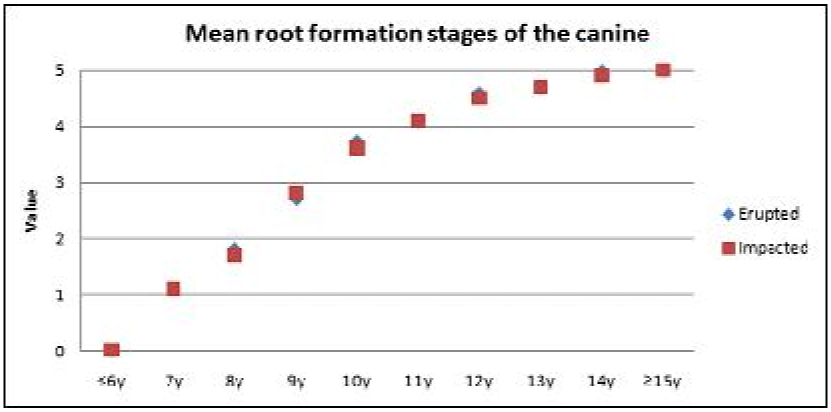

Fig 7. Difference between the mean root formation stages of the impacted canine and the unaffected antimere according to the age of the patients.

study. Moreover, it would be interesting to longitudinally observe radiographs of all patients at different ages to better predict impaction of maxillary canines.

CONCLUSIONS

The vertical distance of the tip of the maxillary canine from the occlusal plane as evident on a panoramic radiograph is a good predictor of impaction of a maxillary canine. Diagnosis of an impacted maxillary canine can be made after 8 years of age, especially if the angulation of the canine with the midline is also considered. Hence, screening of patients to detect an early impaction could be performed at this age.

REFERENCES

1. Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. Eur J Orthod 1988; 10:283-95.
2. Sambataro S, Baccetti T, Franchi L, Antonini F. Early predictive variables for upper canine impaction as derived from posteroanterior cephalograms. Angle Orthod 2005;75:28-34.
3. Lindauer SJ, Rubinstein LK, Hang WM, Andersen WC, Isaacson RJ. Canine impaction identified early with panoramic radiographs. J Am Dent Assoc 1992;123:91-7.
4. Fernández E, Bravo LA, Canteras M. Eruption of the permanent upper canine: a radiologic study. Am J Orthod Dentofacial Orthop 1998;113:414-20.
5. Warford JH Jr, Grandhi RK, Tira DE. Prediction of maxillary canine impaction using sectors and angular measurement. Am J Orthod Dentofacial Orthop 2003;124:651-5.
6. Bishara SE, Kommer DD, McNeil MH, Montagano LN, Osterle LJ, Youngquist HW. Management of impacted canines. Am J Orthod 1976;69:371-87.
7. Wisth P, Norderval K, Bøe O. Comparison of two surgical methods in combined surgical-orthodontic correction of impacted maxillary canines. Acta Odontol Scand 1976;34:53-7.
8. Keur JJ. Radiographic localization techniques. Aust Dent J 1986; 31:86-90.
9. Clark CA. A method of ascertaining the relative position of unerupted teeth by means of film radiographs. Proc R Soc Med Odontol Sect 1910;3:87-90.
10. Ericson S, Kurol J. Radiographic examination of ectopically erupting maxillary canines. Am J Orthod Dentofacial Orthop 1987;91: 483-92.
11. Frykholm A, Malmgren O, Sämfors K, Welander U. Angular measurements in orthopantomography. Dentomaxillofac Radiol 1977;6:77-81.
12. Tronje G, Welander U, McDavid WD, Morris CR. Image distortion in rotational panoramic radiography. III. Inclined objects. Acta Radiol Diagn (Stockh) 1981;22:585-92.
13. Stramotas S, Geenty JP, Darendeliler MA, Byloff F, Berger J, Petocz P. The reliability of crown-root ratio, linear and angular measurements on panoramic radiographs. Clin Orthod Res 2000; 3:182-91.
14. Chaushu S, Chaushu G, Becker A. The use of panoramic radiographs to localize displaced maxillary canines. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;88:511-6.
15. Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. Angle Orthod 1994;64:249-56.
16. Miller BH. The influence of congenitally missing teeth on the eruption of the upper canine. Dent Pract Dent Rec 1963;13: 497-504.
17. Bass TB. Observations on the misplaced upper canine tooth. Dent Pract Dent Rec 1967;18:25-33.
18. Becker A, Smith P, Behar R. The incidence of anomalous maxillary lateral incisors in relation to palatally displaced canines. Angle Orthod 1981;51:24-9.
19. Coulter J, Richardson A. Normal eruption of the maxillary canine quantified in three dimensions. Eur J Orthod 1997;19:171-83.
20. Ericson S, Kurol J. Longitudinal study and analysis of clinical supervision of maxillary canine eruption. Community Dent Oral Epidemiol 1986;14:172-6.
21. Ericson S, Kurol J. Radiographic assessment of maxillary canine eruption in children with clinical signs of eruption disturbance. Eur J Orthod 1986;8:133-40.

Resorbed lateral incisors adjacent to impacted canines have normal crown size

Ilana Brin DMD,[a] Adrian Becker BDS, LDS, DDO,[b] and Yerucham Zilberman DMD[b]
Jerusalem, Israel

The importance of detecting maxillary canine impaction is that it may compromise dental health, particularly since a small but significant proportion of impacted canines is associated with the resorption of the roots of neighboring teeth. It has been shown that the existence of small and peg-shaped lateral incisors is highly correlated with maxillary canine palatal impaction. To date, however, it has not been established whether the root resorption that occurs has a similar correlation or a predilection for one or other types of lateral incisor crown structure. Accordingly, a group of patients with buccally or palatally impacted canines, in which root resorption of the lateral incisor could be diagnosed roentgenographically, was examined and compared with a group of cases with palatally impacted canines, none of which showed root resorption, which served as controls. The mesiodistal crown dimension of the lateral incisor in the experimental group was found to be normal in all patients except three (13%), which was significantly different from the distribution of lateral incisor size in the control group ($p < 0.001$). In the majority of the cases, aggressive root resorption of the lateral incisor root had occurred. We would speculate that in these cases, the normal-sized and early developing lateral incisor root obstructs the deviated eruption path of the canine and consequently stands a considerably greater chance of being damaged by resorption. (AM J ORTHOD DENTOFAC ORTHOP 1993;104:60-6.)

The need for diagnostic awareness regarding resorption of maxillary lateral incisors associated with ectopic eruption of the adjacent canines has been stressed repeatedly by Erickson and Kurol[1-3] and others.[4-6] Many parameters were studied in these publications, mainly those related to canine position.

The structure of the lateral incisor, specifically peg-shaped, small, or missing, has been shown by us[7-9] and others[10] to be a predisposing factor in palatal canine impaction. We have also shown in an earlier publication[7] that there is a close relationship between mesiodistally reduced lateral incisor crown size and a shorter root length. However, this factor has not been investigated in relation to root resorption of the lateral incisor that is adjacent to the impacted canine.

The purpose of this study was to focus on a group of patients who had resorption of the lateral incisor root, which was associated with a deviant eruption pattern of the adjacent canine.

SUBJECTS AND METHODS

The subject material comprised a group of 20 patients in whom 23 lateral maxillary incisors ($n = 23$) showed a degree of root resorption associated with unerupted adjacent canines. For each subject, conventional initial diagnostic orthodontic records were available. The subjects' sex, age, affected side, the existence of root resorption elsewhere, and various other parameters (location of canine, existence of follicular cyst, and mesiodistal width of the lateral incisor) related to the affected canine and lateral incisor, were recorded. Any generalized tendency toward root resorption was determined by scrutinizing the pretreatment intraoral roentgenograms for idiopathic resorption of the roots of teeth other than the lateral incisors.

The canine-related parameters assessed were (a) buccal or palatal location of the unerupted canine, as assessed from the available roentgenograms[5] and from clinical observation at the time of surgical exposure; and (b) presence and size of a canine follicular cyst assessed according to Shear[11] from the same roentgenograms. The diagnostic criterion for a cyst (in contrast to merely a dilated follicle) was that its pericoronal width must be at least 3 mm.

The lateral incisor-related parameters were (1) the lateral incisor mesiodistal crown size as evaluated according to Becker et al.[7] The maxillary lateral incisor was considered as peg-shaped, when its greatest mesiodistal width was at the cervical margin; small, when its mesiodistal width equalled or was smaller than that of its mandibular counterpart; and normal when its mesiodistal width was larger than that of its mandibular counterpart. (2) The degree of its root resorption as assessed on the mesial and distal aspect separately according to a modification of the method of Malmgren et al.[12]: 1st degree resorption, irregular root contour; 2nd degree, resorption amounting to less than 2 mm of the assessed original

From the Department of Orthodontics, Hebrew University-Hadassah School of Dental Medicine.
[a]Senior Lecturer.
[b]Clinical Associate Professor.

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Table I. Distribution of the subjects in the experimental group according to sex, age, occurrence of idiopathic root resorption, canine, and lateral incisor related parameters (20 subjects with 23 teeth)

Sex:	8 boys 12 girls
Mean age in years	12.3 (range 11 to 16)
Idiopathic resorption	In 3 patients
Affected side:	9 right 14 left
Location of the impacted canine:	20 palatal 3 buccal
Canine follicular cyst:	In 9 teeth
MD width of the affected lateral incisor crown:	20 normal 3 small

Table II. Distribution of lateral incisor crown size versus root resorption

	Normal lateral incisors	*Small lateral incisors*	*Total*
Resorbed lateral incisors	20 87%	3 13%	23 100%
Unresorbed lateral incisors	66 52%	60 48%	126 100%

$p < 0.001$.

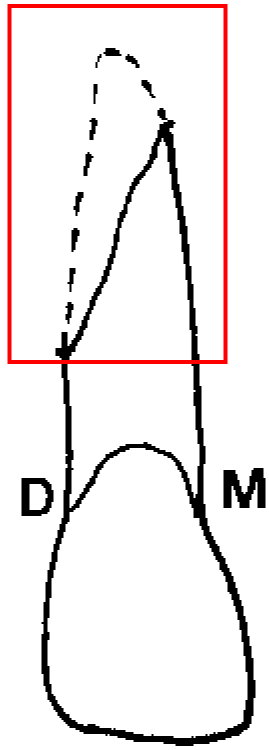

Fig. 1. Schematic representation of oblique root resorption: fourth degree resorption on distal aspect; 2nd degree resorption on mesial aspect; difference of 2 indicating diagonal root resorption of 2nd degree.

root length; 3rd degree, resorption of between 2 mm and one third of the assessed original root length; 4th degree, root resorption exceeding one third of the assessed original root length.

The values for both mesial and distal root resorption were recorded. In addition, any difference in classification between them was noted and used to indicate the presence of oblique root resorption (Fig. 1).

To relate lateral incisor mesiodistal crown size with the occurrence of resorption of its root in cases of impaction of the adjacent canine, a control group drawn from a previous study[7] was used. This group consisted of patients with unilateral or bilateral positioning of maxillary canines representing all the impacted canine cases in 633 consecutive patients of an orthodontic practice. One hundred and twenty-one lateral incisors that were situated adjacent to impacted canines served this purpose. The chi squared test (1 df) was applied to compare the distribution of normal and small lateral incisors in the control group ($n = 121$) with that in the group of resorbed lateral incisors ($n = 23$).

RESULTS

The results concerning the examination of the sample are presented in Table I. The resorbed lateral incisors were more prevalent among girls (3 to 2). The mean age at the beginning of the orthodontic treatment was 12.3 years (range 11 to 16 years of age). In the majority of the cases examined, no tendency to resorption of the roots of other teeth before treatment could be observed. However, if the three subjects (all girls with four resorbed lateral incisors) with resorbed teeth other than lateral incisors are excluded, the ratio of female to male patients changed to 9 to 8, and the number of lateral incisors was reduced to 19. Since the lateral or oblique pattern seen in the affected lateral incisors contrasts very strongly with the blunting pattern of resorption of the other teeth, these four teeth were not excluded from further analyses.

Marginally, more left lateral incisors were affected (14 of 23), and the position of the unerupted canine was predominantly palatal (20 of 23). In less than half of the cases an eruptive cyst was present. The mesiodistal dimension of the affected lateral incisor was normal in all but three. Comparison with the control group is presented in Table II. The results indicate that the chances for root resorption of a lateral incisor adjacent to an impacted canine are significantly higher ($p < 0.001$) when the lateral incisor is normally sized.

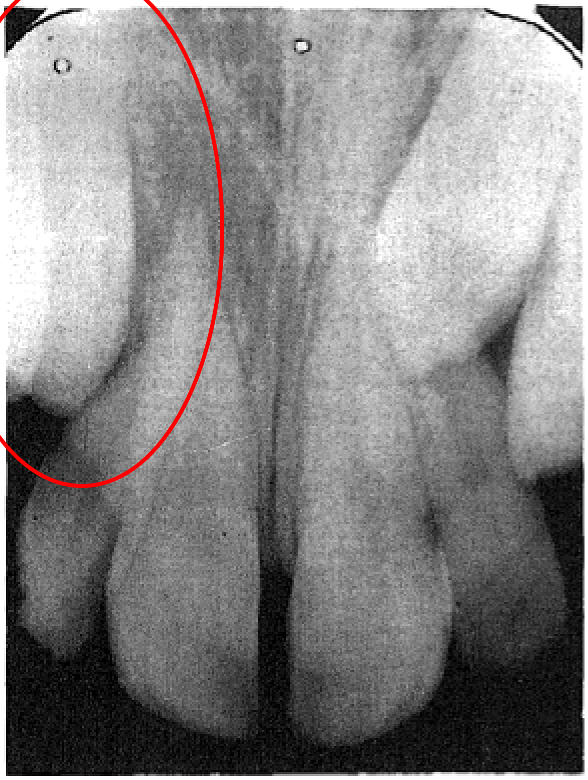

Fig. 2A. Periapical roentgenogram demonstrating palatally impacted canines and diagonal root resorption of right lateral incisor.

Most of the resorption on the mesial (56.5%) and distal (82.6%) aspects of the lateral incisors was severe (3rd or 4th degree). In nine teeth (39%), oblique resorption had occurred (Table III). In two cases considerable root resorption of the central incisors could be seen.

DISCUSSION

The phenomenon of lateral incisor root resorption has been found to occur in 12% of a sample of patients with an impacted maxillary canine.[12] The severity of the damage caused, as we have shown here, may be extreme (Table III). Almost 40% of the affected teeth demonstrated oblique root resorption, whereas in the others, lateral resorption was observed. In the 3rd or 4th degree resorption cases, special attention will be required at the end of the orthodontic treatment. Given the fact that few stage 1 and 2 cases were actually found, and taking into account the young average age of this sample of patients, it would seem reasonable to assume that these are merely the early signs of what threaten to become severe resorption cases, too. In other words, we would speculate that resorption of this etiologic condition is severe and rapid.

Table III. Distribution of the degree of mesial, distal, and oblique root resorption of the maxillary lateral incisors (number of affected teeth)

Degree of root resorption	*Mesial*	*Distal*	*Oblique*
1st degree	7	1	2
2nd degree	3	3	5
3rd degree	3	5	2
4th degree	10	14	—
Total	23	23	9

Moreover, we would point out that the roentgenographic visualization and assessment of resorption may be substantially less than the true extent of the insult, because of the two-dimensional representation of a three-dimensional disease process. This may be clearly illustrated with reference to one of the patients with bilateral impaction who was followed-up in this study. Roentgenographic examination indicated first degree root resorption of the left lateral incisor only (Fig. 2A). Both maxillary lateral incisors were extracted in the course of the orthodontic treatment and, on examination, an advanced and spiralling resorption process was observed in both teeth (Fig. 2B). This bears witness to the inadequacy of conventional roentgenography in defining and allowing for accurate interpretation of the actual resorption status of the affected incisor.

In the literature, root resorption associated with an impacted canine was found to be more prevalent in females.[2,3] In our study, however, although more girls (60%) were affected, the sample is too small to draw binding conclusions. Given, also, that a tendency toward general root resorption was not found (idiopathic root resorption seen only in three subjects), it would seem to preclude the possibility of an hormonal systemic factor.

Palatal displacement of canines has been associated with anomalous maxillary lateral incisors,[7,9,10,14] which characteristically develop late. In three of these studies, half the cases with palatally positioned canines presented with anomalous lateral incisors. These findings were considered to lend credence to the view that it is a lack of guidance during the critical stages of canine development that leads to palatal displacement.[14] It was assumed that this guidance is usually present when the lateral incisor is of normal size. However, no explanation is available for the other 50% of the cases with impacted canines which present with normal-sized lateral incisors. Trauma to the region may suggest a possible etiologic factor,[15] however, its occurrence is not always remembered by the patient or parents, or recorded by the dentist.

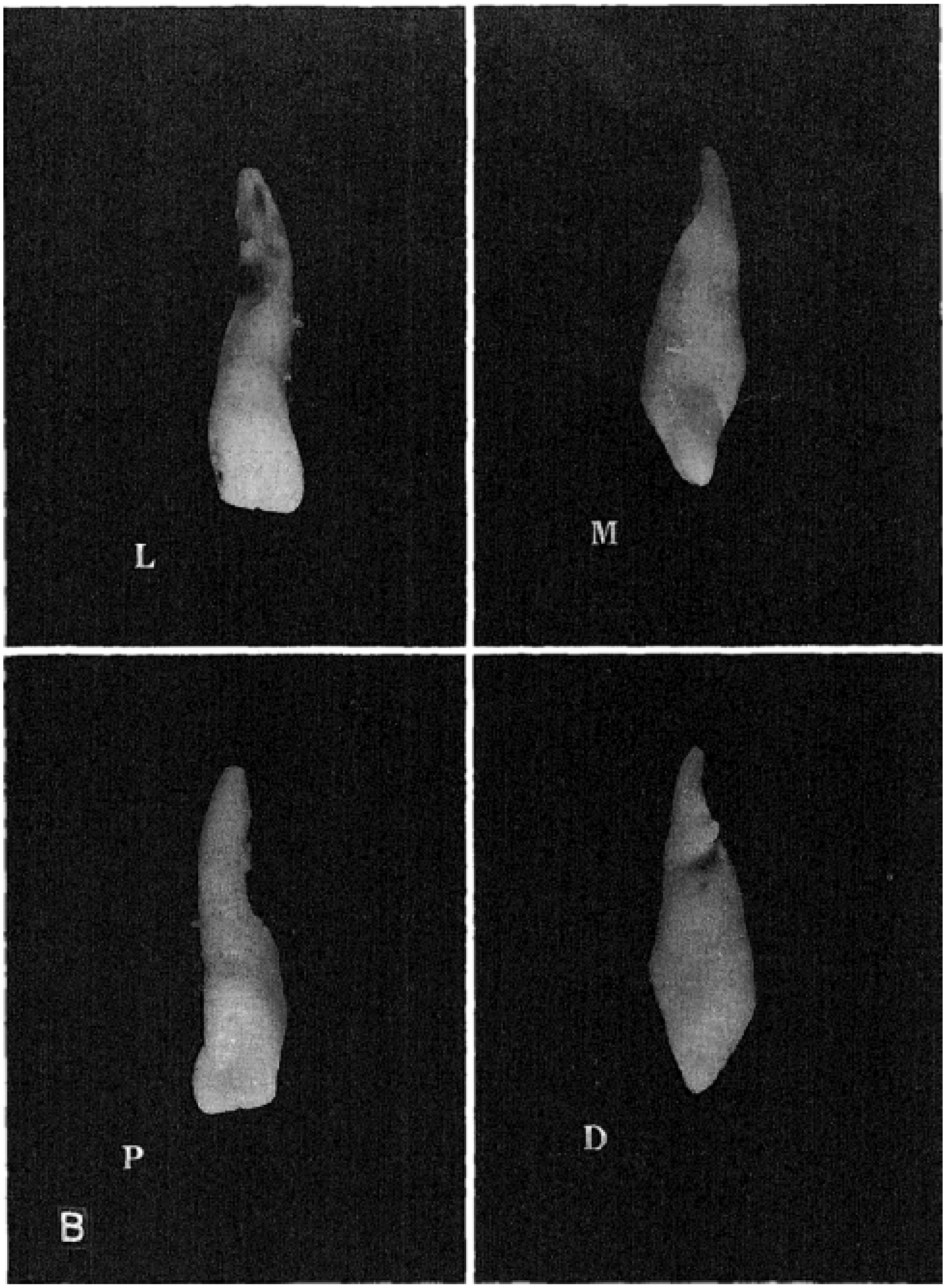

Fig. 2B. Labial *(L)*, mesial *(M)*, palatal *(P)*, and distal *(D)* aspects of extracted right maxillary lateral incisor. Note the severe root resorption and its tortuous pattern.

In regard to the width of the canine dental follicle, our findings concurred with those of Ericson and Kurol[2] who could not correlate resorption with a dilated follicle or cyst in the region.

In this study, the location of the impacted canine was found to be predominantly palatal, as has been reported in other studies on impacted canines.[1] However, in only three cases (13%) was resorption found on a lateral incisor with a mesiodistally small crown, whereas in another case, root dwarfism was noted.

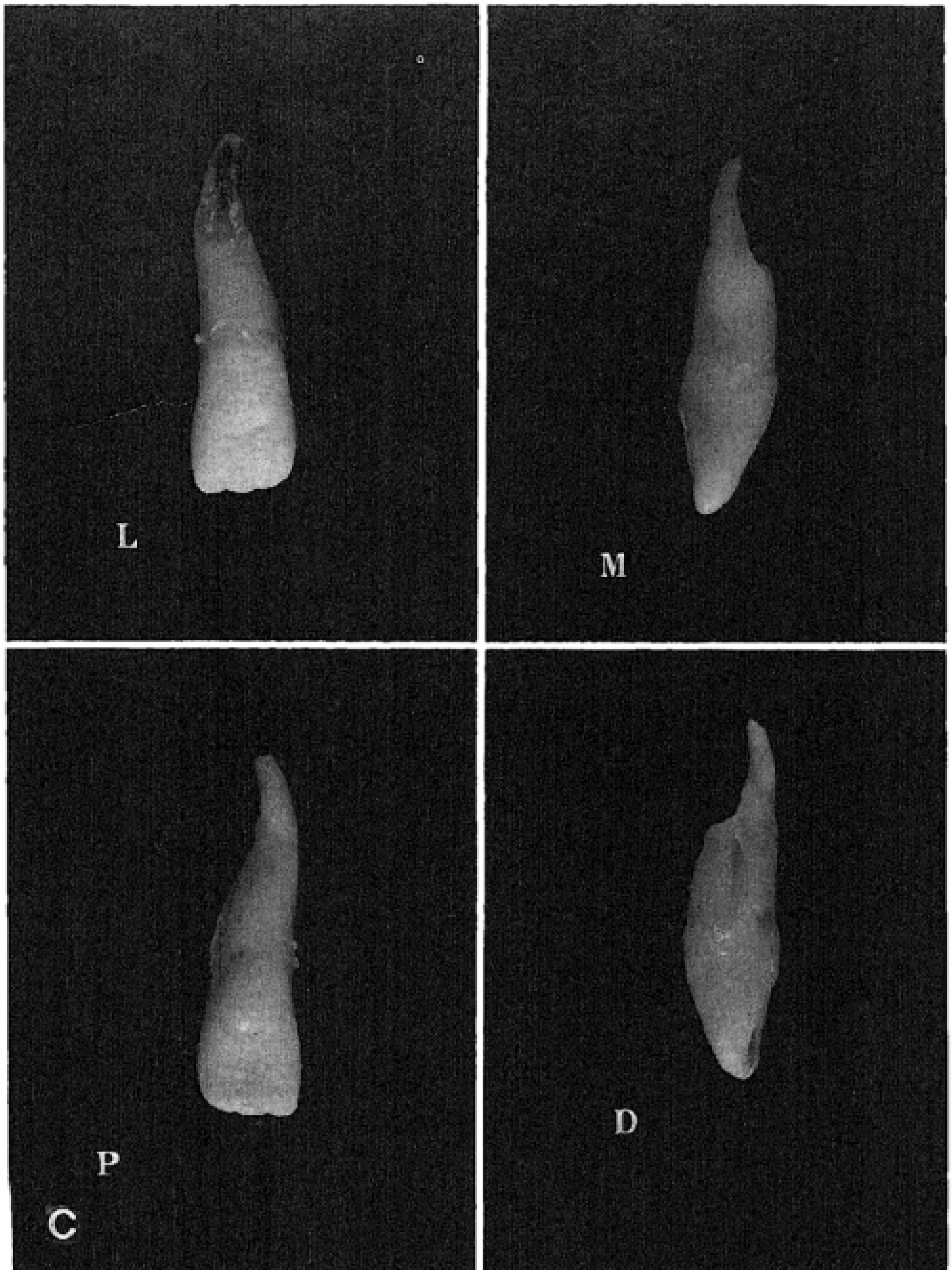

Fig. 2C. Labial *(L)*, mesial *(M)*, palatal *(P)*, and distal *(D)* aspects of extracted left maxillary lateral incisor. Note the severe root resorption and its tortuous pattern which could not be detected on the periapical roentgenogram.

Thus, in our sample, the affected lateral incisors were found to be normal size in almost all patients, the distribution being significantly different ($p < 0.001$) from that in a control sample of unaffected lateral incisors adjacent to impacted canines.

From these results and the findings of Becker et al.,[7] it may be speculated that, in cases of canine impaction, the normal sized lateral incisor root obstructs the deviated path of eruption of the canine and is damaged as a consequence; whereas in cases with anoma-

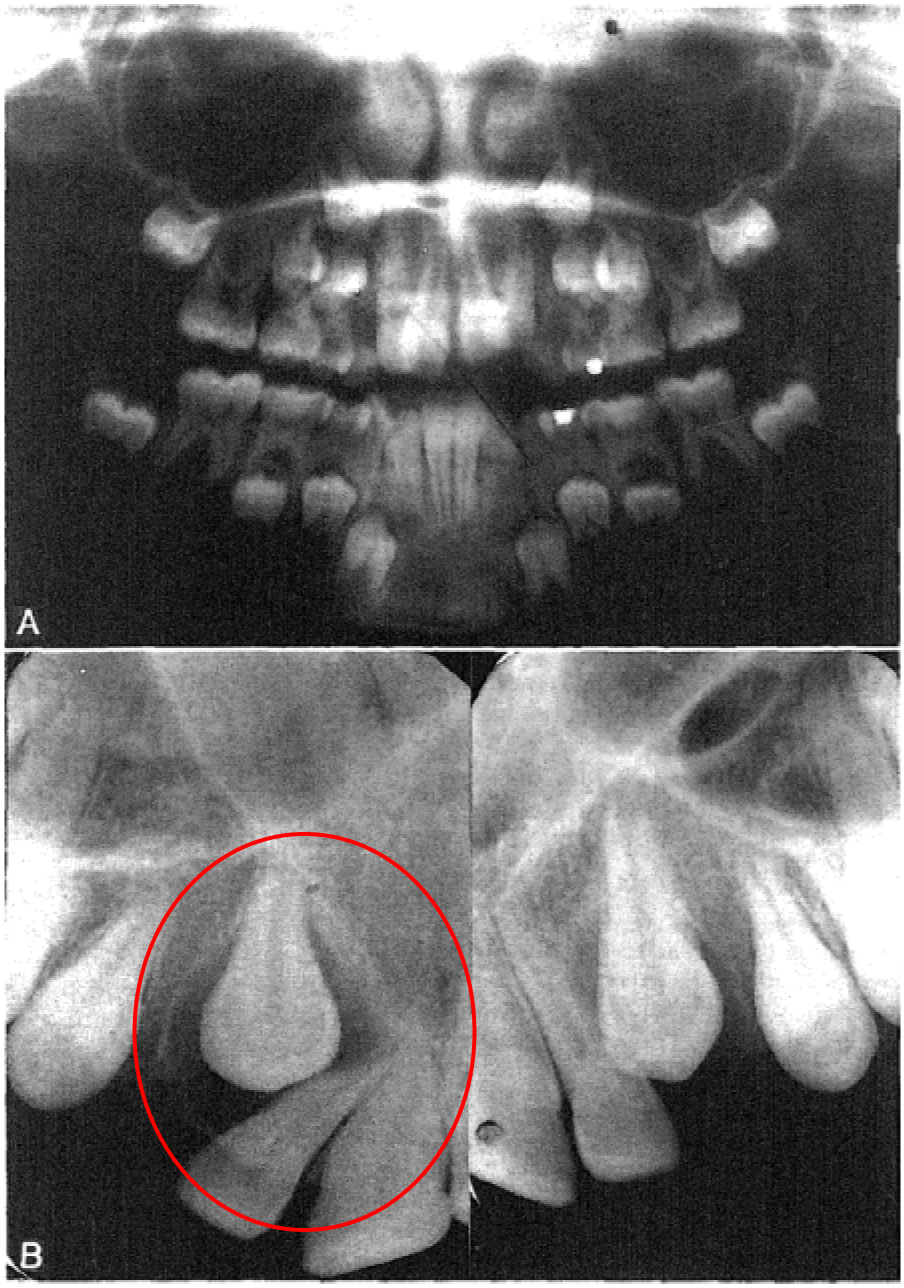

Fig. 3. A, Panoramic view of an 8-year old patient. Note the apparently normal position and development of the maxillary canines. B, Periapical roentgenograms of same patient 3 years later. Note unerupted maxillary canines and the resorption of the root of the right lateral incisor.

lous lateral incisors (peg shaped and/or a small mesiodistal crown width), their smaller[6] and late developing[7] roots are more easily bypassed and not endangered by the impacted tooth.

From this, considering the limitations of the relatively small sample, we would conclude that special care should be taken in the follow-up and treatment of patients with impacted canines that are adjacent to normal sized lateral incisors. The orthodontist should be encouraged to begin treatment earlier in these cases, perhaps as soon as impaction is diagnosed.

It is interesting to note that some of the patients had been under observation for several years, during the mixed dentition period and had not started orthodontic treatment. Their original orthodontic problems were not linked to canine displacement, which could not be detected at that stage, neither from clinical nor from roentgenographic examination (Fig. 3, *A*). It was only several years later and relatively late in its development, that the path of eruption of the permanent canine appeared to have changed and, in so doing, led to damage of its neighboring tooth (Fig. 3, *B*). This is in agreement with the conclusion of Ericson and Kurol[1] that a final unfavorable eruption of the permanent canine is normally not predictable from early roentgenographic investigation.

We thank Mr. I. Binot, MSc, for his help with the statistical evaluation.

REFERENCES

1. Ericson S, Kurol J. Radiographic assessment of maxillary canine eruption in children with clinical signs of eruption disturbance. Eur J Orthod 1986;8:133-40.
2. Ericson S, Kurol J. Resorption of maxillary lateral incisors caused by ectopic eruption of canines. AM J ORTHOD DENTOFAC ORTHOP 1988;94:503-13.
3. Ericson S, Kurol J. CT diagnosis of ectopically erupting maxillary canines—a case report. Eur J Orthod 1988;10:115-20.
4. Brown JD, Matthews RW. Apical resorption of a maxillary lateral incisor from a misplaced canine in a 17 year old. A case report. Br J Orthod 1981;8:3-5.
5. Sasakura H, Yoshida T, Murayama S, Hanada K, Nakajima T. Root resorption of upper permanent incisor caused by impacted canine. Int J Oral Surg 1984;13:299-306.
6. Regan D, Craig GT. External resorption of a maxillary lateral incisor by a labially placed canine: pathology and management. Br J Orthod 1988;15:251-7.
7. Becker A, Smith P, Behar R. The incidence of anomalous lateral incisors in relation to palatally displaced cuspids. Angle Orthod 1981;51:24-9.
8. Becker A, Zilberman Y, Tsur B. Root length of lateral incisors adjacent to palatally-displaced maxillary cuspids. Angle Orthod 1984;54:218-25.
9. Brin I, Becker M, Shalhav M. Position of the maxillary permanent canine in relation to anomalous or missing lateral incisors: a population study. Eur J Orthod 1986;8:12-6.
10. Oliver RG, Mannion JE, Robinson JM. Morphology of the lateral incisor in cases of unilateral impaction of the canine. Br J Orthod 1989;19:9-16.
11. Shear M. Cysts of the oral regions. 2nd ed. Bristol: Wright PSG, 1983:53.
12. Malmgren O, Goldson L, Hill C, Petrini L, Lundberg M. Root resorption after orthodontic treatment of traumatized teeth. AM J ORTHOD 1981;82:24-9.
13. Ericson S, Kurol J. Radiographic examination of ectopically erupting maxillary canines. AM J ORTHOD DENTOFAC ORTHOP 1987;91:483-92.
14. Becker A. Etiology of maxillary canine impactions. AM J ORTHOD 1984;86:437-8.
15. Brin I, Solomon Y, Zilberman Y. Trauma as a possible etiologic factor in maxillary canine impaction. [in press].

Reprint requests to:
Dr. I. Brin
Department of Orthodontics
Hebrew University-Hadassah School of Dental Medicine
POB 1172, Jerusalem
Israel

Changes in condylar position and occlusion associated with maxillary expansion for correction of functional unilateral posterior crossbite

Karen L. Hesse, DDS, MSD,[a] Jon Årtun, DDS, Dr. Odont.,[b] Donald R. Joondeph, DDS, MS,[c] and David B. Kennedy, BDS, MSD, FRCD(Can)[d]
Seattle, Wash., and Vancouver, British Columbia, Canada

The purpose of this study was to confirm that correction of functional posterior crossbite through maxillary expansion is associated with a change in condylar position and occlusal relationships, and to determine whether maxillary expansion is associated with autonomous increase in mandibular arch width. Pretreatment and posttreatment study models of 61 patients ages 4.1 to 12.0 years (mean 8.5 years, SD 1.5) were available after maxillary expansion with a Quad Helix or a Haas expander for correction of a functional posterior crossbite. Pretreatment and posttreatment tomograms were available for 22 of the patients. Tomographic evaluation revealed that the condyles moved posteriorly and superiorly on the noncrossbite side from before to after treatment ($p < 0.05$). No differences were observed on the crossbite side. Superior joint space was greatest on the noncrossbite side before treatment, whereas, conversely, it was greatest on the crossbite side after treatment ($p < 0.05$). Relative condylar position was more anterior on the noncrossbite side before treatment ($p < 0.05$), but similar on both sides after treatment. Molar and canine relationships were more Class II on the crossbite side before treatment ($p < 0.01$ and < 0.05, respectively) and similar on both sides after treatment. A significant reduction in midline deviation was seen from before to after treatment ($p < 0.001$). A small, but significant autonomous increase in mandibular intermolar width ($p < 0.001$) occurred concomitant with the maxillary expansion. (Am J Orthod Dentofac Orthop 1997;111:410-8.)

Unilateral posterior crossbite is one of the most frequently occurring malocclusions in the deciduous and mixed dentitions, with a reported incidence of 7% to 23%.[1-7] In the early stages, such crossbites are associated with a lateral functional shift of the mandible in approximately 80% of cases.[7,8] As a result, an asymmetric condylar position has been documented in maximum intercuspation, with the crossbite side condyle being forced upward and backward, while the noncrossbite side condyle is distracted relative to the glenoid fossa.[9-11] This type of malocclusion is frequently corrected early through bilateral maxillary expansion and possibly occlusal grinding, eliminating the occlusal interferences and deviation of the mandible on closure.[12-15] As a result, the condyles may be expected to change from an asymmetric to a more symmetric position after treatment.[9] Few studies, however, have documented such changes. In one such study, where transcranial radiographs[9] were used with a sample size of only 10, only superior and anterior joint space was measured. The use of transcranial radiographs also introduces greater potential methodologic error, as they do not allow detailed description of the condyle-fossa relationship because of compromised image quality and projection effects.[16] With elimination of the mandibular shift, molar relationship may be expected to change in the direction of becoming more symmetric, with a concomitant reduction in the midline deviation after treatment. Such changes are poorly documented. Authors have also suggested that maxillary expansion is associated with spontaneous width increase in the mandibular arch.[17-20]

Inferences from studies on frequency of unilateral crossbite in various age groups,[1-7] as well as follow-up studies of untreated subjects, suggest that unilateral crossbite develops early and has a low rate of spontaneous correction.[1,5,7,22] The fact that a functional shift is rarely detected in adults with unilateral crossbite[10,23] may be an indication of adaptive remodeling changes of the temporomandibular joint with age, with development of a skeletal asymmetry.[10,23-25] Accordingly, the verification of

[a]Graduate student, University of Washington, Seattle.
[b]Professor, University of Washington, Seattle.
[c]Associate professor, University of Washington, Seattle.
[d]Private practice, Vancouver, British Columbia.
Reprint requests to: Dr. Jon Årtun, University of Washington, Department of Orthodontics, SM 46, Seattle, WA 98195.

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a change from asymmetric to more symmetric condylar position concomitant with treatment of functional posterior crossbite in children would support the need for early intervention to minimize the potential for development of a skeletal asymmetry.

The purpose of this study was to confirm that early correction of functional posterior crossbite through maxillary expansion is associated with a change in condylar position and occlusal relationships, and to determine whether maxillary expansion is associated with spontaneous increase in mandibular arch width.

MATERIALS AND METHODS

Sample

A total of 61 patients ages 4.1 to 12.0 years (mean 8.5 years, SD 1.5), after correction of functional unilateral crossbite by one of the authors (D.K.), were included in this study. At the time of pretreatment records (T1), the patients exhibited a minimum of two molars in crossbite on one side only, with the mandibular dental midline shifted toward the crossbite side. No patients demonstrated anterior crossbite, Class III tendency, or missing deciduous molars. Dental histories were negative for previous orthodontic treatment, trauma, or growth abnormalities. All patients had experienced slow maxillary expansion with a Quad helix or a Haas expander until crossbite and shift were eliminated. Active treatment time ranged from 6 to 14 weeks. Posttreatment records were taken after a retention period of approximately 3 months (T2). T1 and T2 study models were available for all patients. In addition, temporomandibular joint tomograms were taken in closed lateral view of 25 patients at T1. Of these, 22 complied with the T2 tomographic radiographs. Attempts were made to take all records in centric occlusion.

Tomographic Measurements

All tomograms were taken at Wilson Radiographic Center in Vancouver, Canada, using a standardized procedure. Most patients had a submental vertex (SMV) radiograph to determine which angulation and depth of the linear section would pass through the center of the condyle. When an SMV radiograph was not available, a standard 20° posterior correction angle was used. Most joints were imaged at two or three different depths of cut. At the posttreatment radiographic session, a few joints were exposed only once if the image was determined to be of sufficient quality. The number of tomographic cuts per joint at T1 and T2 ranged from one to four with an average of two. For each joint, one representative cut was selected for measurement on the basis of clarity and contrast of condyle and fossa, similarity of depth of cut, angulation, and joint anatomy at T1 and T2. The noncrossbite side images of one patient were eliminated because of unsatisfactory match. After random coding for identification, the tomograms were projected onto a screen at about X7 magnification, oriented to appear as a left-sided view. Linear measurements of the smallest anterior, superior, and posterior joint space (Fig. 1) were made directly on the screen with a Fowler Ultra-Cal III electronic caliper to the nearest 0.014 mm, the nearest whole millimeter on the magnified image. The measurements were made twice, at least 1 week apart.

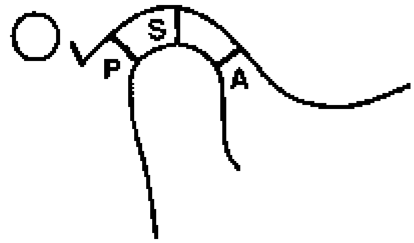

Fig. 1. Locations of measurements of narrowest anterior (*A*), posterior (*P*) and superior (*S*) interarticular spaces in temporomandibular joint tomograms. Relative condylar position is expressed as[27]:

$$\frac{P - A}{P + A} \times 100$$

After joint space measurements, each pair of T1 and T2 tomograms for each joint was coded randomly. Each pair was traced simultaneously to facilitate identification of identical anatomic structures. The center point of the T1 condylar tracing (A1) was marked and a second reference mark (B1) was placed 20 mm from A1 on a line parallel to the posterior border of the ramus. The points A1 and B1 were then transferred onto the T2 tracing (A2 and B2, respectively) superimposing the condylar tracings according to best fit. The tracings were then superimposed on the best fit of the fossa by using anterior and posterior structures of the cranial base for rotational correction. A horizontal reference line was constructed from the most inferior border of the articular eminence to the superior border of the petrotympanic fissure on the superimposed tracing. A vertical reference line was constructed perpendicular to this line through A1. Lines were also drawn from A1 to B1 and from A2 to B2. Horizontal (Dx) and vertical (Dy) movement of the condyle from T1 to T2 was measured as the distances between A1 and A2 along the horizontal and vertical reference lines, respectively (Fig. 2). Rotational change in condylar position from T1 to T2 was measured as the angle between the lines from A1 to B1 and from A2 to B2 (Fig. 2).

Study Model Measurements

For each patient, the T1 and T2 study models were evaluated simultaneously and similar points were marked on the tips of each deciduous canine, the mesiolingual and mesiobuccal of each maxillary first molar, and the mesiolingual of each mandibular first molar cusp. A few patients were missing canines. The second deciduous molar was

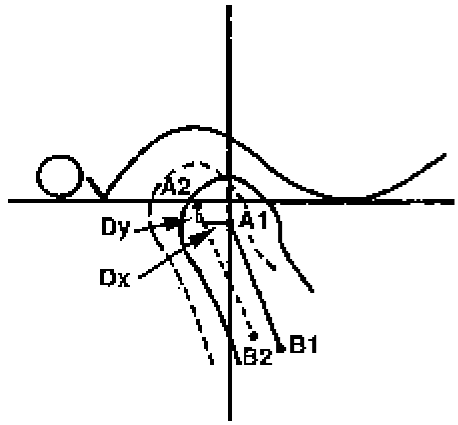

Fig. 2. Superimposition showing measurement of horizontal (*Dx*) and vertical (*Dy*) movement of condyle and rotational change in condylar position (angle between lines from *A1* to *B1* and from *A2* to *B2*) from before to after treatment of functional posterior crossbite (see text).

used if the permanent molar was not present at T1. The midline was interpreted as the contact point of the central incisors. In situations with a diastema or missing incisors, the midline was recorded as the midpoint of the space between mesial edges of adjacent contralateral teeth, using the incisive papilla as an additional guide in the maxilla, and marked on the model. In addition, lines were scribed on the facial surfaces of the teeth, through the cusp tip marks and perpendicular to the occlusal plane. Finally, a line was scribed in the buccal groove of the mandibular first molar.

After random coding for identification, arch width, molar and canine relationship, and any midline deviation was measured on each study model, with a Fowler Ultra-Cal III caliper to the nearest 0.1 mm, eliminating cases with missing deciduous canines. Each measurement was made twice at least 1 week apart. Arch width was measured as the distance between contralateral marks at the tip of the canine and mesiolingual molar cusps. Molar relationship was recorded as zero if the reference lines were flush. A negative measurement indicated a Class III relationship and a positive a Class II relationship. The terminal plane of the deciduous second molars was used at both T1 and T2 in situations where a first permanent molar was not erupted at T1, and a zero recording indicated a flush terminal plane. Canine relationship was recorded as zero if the cusp tip of the maxillary deciduous canine occluded into the distal contact point of the mandibular deciduous canine. Positive and negative recordings were given as for molar relationship. Midline deviation was recorded as the distance along the occlusal plane between the contact point of the maxillary and mandibular central incisors or the reference lines.

Error of the Method

Method error was calculated according to the formula:

$$\sqrt{\Sigma D^2/2N}$$

Where D is the difference between duplicated measurements and N is the number of double measurements.[26] The errors were 0.22 and 0.20 mm for canine and molar relationship, 0.17 mm for midline deviation, 0.13 and 0.12 mm for maxillary and mandibular intercanine width, and 0.14 and 0.10 mm for maxillary and mandibular intermolar width, respectively. The errors for joint space measurements were 0.22 mm for anterior, 0.20 mm for superior, and 0.29 mm for posterior joint space. The error for calculated relative condylar position was 6.49%. The method error for evaluation of condylar movement was determined by repeating the tracing, superimposition, and measurement of tomograms for 20 joints, and calculated as previously mentioned. The errors were 0.22 mm for Dx, 0.34 mm for Dy, and 1.60° for rotational change.

Statistical Analysis

The duplicated data were pooled, and the averaged value for each measurement was used for the statistical analysis. The relative position of each condyle at each time period was calculated according to the formula (Fig. 1):

$$\frac{\text{posterior} - \text{anterior interarticular joint space}}{\text{posterior} + \text{anterior interarticular joint space}} \times 100\%$$

A zero value indicated a concentric location of the condyle within the fossa. A positive value indicated an anterior and a negative a posterior condylar position (in %).[27] For each joint, change from T1 to T2 in relative condylar position, in anterior, superior and posterior joint spaces, in Dx and Dy, and in rotation was calculated. Also, contralateral differences in relative condylar position and superior joint space were calculated at T1 and T2. Student's t test for paired data was used to determine any statistically significant differences. Pearson's product-moment correlation coefficients were calculated between change in relative condylar position and superior joint space from T1 to T2, and between Dx and Dy.

For each patient, change from T1 to T2 in intermolar and intercanine width, in midline deviation, and in molar and canine relationship on each side was calculated, in addition to contralateral differences in molar and canine relationship at T1 and T2. Student's t test for paired data was used to determine any statistically significant differences. Pearson's product-moment correlation coefficients were calculated to test for any associations between changes in molar and canine relationship and midline relationship from T1 to T2.

Pearson's product-moment correlation coefficients were calculated between changes in relative condylar position, in superior joint space, in Dx and in Dy of each

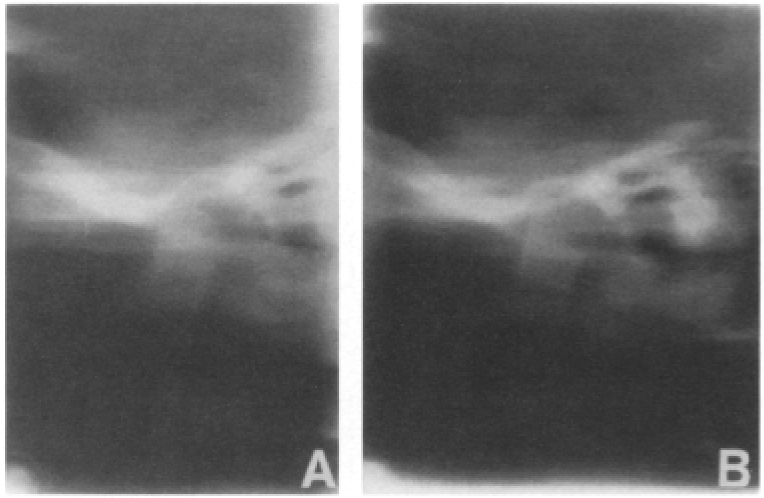

Fig. 3. Tomograms of noncrossbite side condyle made before (**A**, T1) and after (**B**, T2) treatment of patient presenting with functional posterior crossbite. Note more posterior and superior position of condyle at T2.

Table I. Anterior, superior and posterior joint space and relative condylar position before (T1) and after (T2) as well as change from before to after (T2-T1) treatment of functional posterior crossbite in the deciduous and mixed dentitions

	Crossbite side (n = 22)						*Noncrossbite side (n = 22)*					
	T1		*T2*		*T2-T1*		*T1*		*T2*		*T2-T1*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Anterior (mm)	1.69	0.45	1.76	0.58	0.06	0.45	1.51	0.42	1.74	0.34	0.23	0.30**
Superior (mm)	3.37	0.65	3.30	0.66	0.23	0.64	3.52	0.84	2.98	0.51	0.54	0.76**
Posterior (mm)	3.13	0.89	3.29	0.95	0.16	0.66	3.78	1.32	2.80	0.73	−0.98	1.20**
Relative position (%)	28.55	19.77	29.18	19.49	0.62	16.08	40.44	19.66	22.05	16.19	−18.38	17.79***

$^{**}p < 0.01$; $^{***}p < 0.001$.

joint from T1 to T2, and changes in corresponding molar, canine, and midline relationship from T1 to T2.

RESULTS

Changes in Joint Space and Relative Condylar Position

Anterior joint space increased, superior and posterior joint space decreased, and relative position of the condyle changed to a more posterior position within the fossa from T1 to T2 on the noncrossbite side (Fig. 3, Table I). No significant differences were observed on the crossbite side from T1 to T2 (Fig. 4). Of the two sides, superior joint space was greatest on the *noncrossbite* side at T1 (mean 0.45 mm, SD 0.85, $p < 0.05$, Fig. 5) and on the crossbite side at T2 (mean 0.33 mm, SD 0.69, $p < 0.05$, Fig. 6). Also, relative condylar position was more anterior on the noncrossbite than on the crossbite side at T1 (mean 11.89%, SD 20.70, $p < 0.05$, Fig. 5). The relationship was reversed at T2 but was not statistically significant (mean 7.13%, SD 14.72, $p > 0.05$, Fig. 6). An association was found between amount of change to a more posterior relative condylar position and a decrease in superior joint space on the noncrossbite side($r = 0.77$, $p < 0.001$), whereas the amount of change to a more anterior relative condylar position was associated with an increase in superior joint space on the crossbite side ($r = 0.45$, $p < 0.05$).

Condylar Movement

The condyles moved posteriorly and superiorly ($p < 0.05$) on the noncrossbite side from T1 to T2.

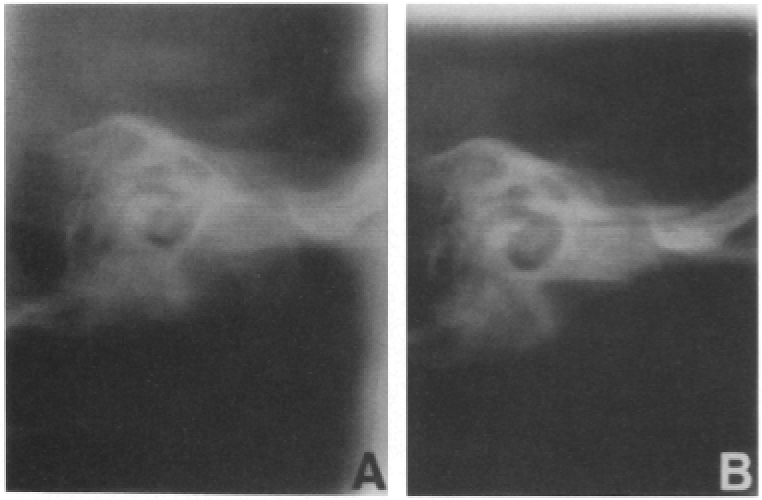

Fig. 4. Tomograms of crossbite side condyle made before (**A**, T1) and after (**B**, T2) treatment of patient presenting with functional posterior crossbite. Note minor differences in condylar position.

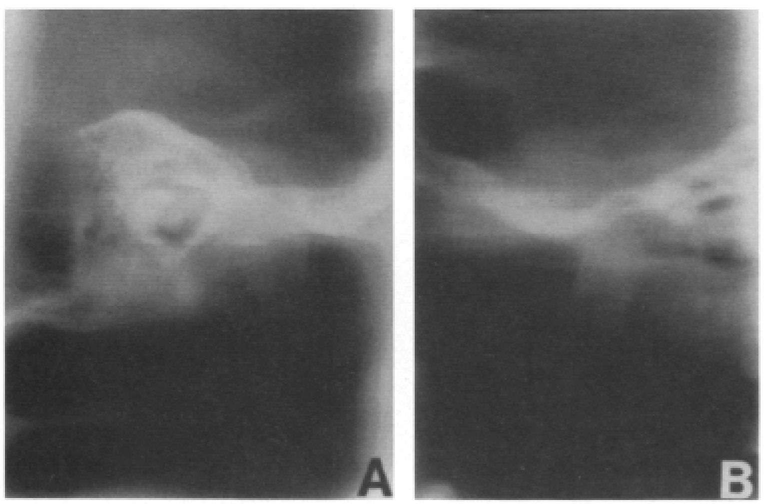

Fig. 5. Tomograms of crossbite (**A**) and noncrossbite (**B**) side condyle made before treatment of patient presenting with functional posterior crossbite. Note larger superior joint space and more anterior condylar position on noncrossbite side.

No significant movement was observed on the crossbite side, and rotational change of the condylar neck was not significant on either side (Table II). An association was found between the amount of posterior and the amount of superior movement of the noncrossbite side condyle ($r = 0.60$, $p < 0.01$). No such association was found for the crossbite side condyle ($r = 0.36$, $p > 0.05$).

Changes in Occlusion

Molar and canine relationship were less Class II at T2 than at T1 on the crossbite side ($p < 0.01$ and < 0.05, respectively). On the noncrossbite side, the differences were not statistically significant (Table III). At T1, molar and canine relationship were more Class II on the crossbite than on the noncrossbite side (mean 0.96 mm, SD 1.43 and mean 0.75 mm, SD 1.28, respectively, $p < 0.001$). The differences at T2 were not significant (mean 0.28 mm, SD 1.16 and mean 0.28 mm, SD 1.14, respectively, $p > 0.05$). The mandibular midline was 2.47 mm (SD 1.04) to the crossbite side of the maxillary midline at T1 and only 0.63 mm (SD 1.03) at T2. This change was statistically significant ($p < 0.001$) and also

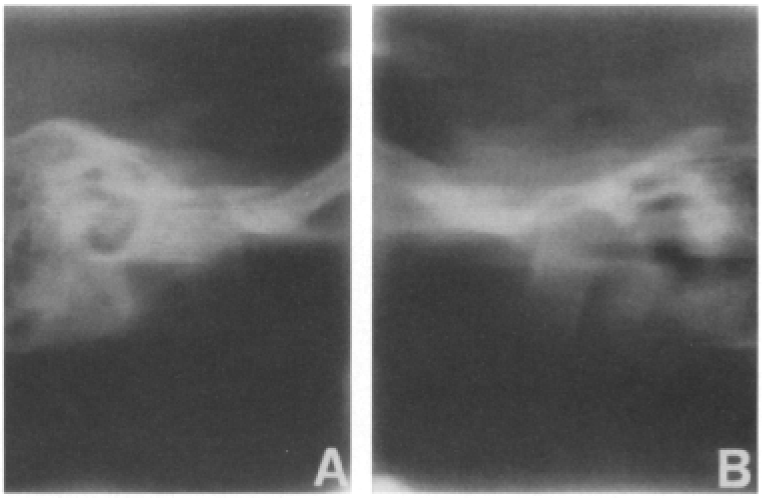

Fig. 6. Tomograms of crossbite (**A**) and noncrossbite (**B**) side condyle made after maxillary expansion and elimination of functional shift. Note minor differences in condylar position.

Table II. Horizontal (Dx) and vertical (Dy) movement of the condyle and rotation of the condylar neck from before to after treatment of functional posterior crossbite in the deciduous and mixed dentition. (Negative values indicate posterior and inferior movement and upward and forward rotation)

	Crossbite side $n = 22$		*Noncrossbite side* $n = 22$	
	Mean	*SD*	*Mean*	*SD*
Dx (mm)	0.06	0.65	−1.00	1.06***
Dy (mm)	−0.18	0.71	0.54	0.75**
Rotation (deg)	−0.05	2.42	0.88	2.40

$^{**}p < 0.01$; $^{***}p < 0.001$.

Table III. Canine and molar relationship before (T1) and after (T2) as well as change from before to after (T2-T1) treatment of functional posterior crossbite in deciduous and mixed dentitions. (Positive values indicate Class II relationship)

	Crossbite side ($n = 58$ *canine, 61 molar*)						*Noncrossbite side* ($n = 56$ *canine, 61 molar*)					
	T1		*T2*		*T2-T1*		*T1*		*T2*		*T2-T1*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Canine (mm)	2.10	1.45	1.82	1.33	0.28	0.97*	1.43	1.22	1.55	1.37	0.12	1.12
Molar (mm)	1.85	2.08	0.95	1.91	−0.90	1.11**	0.88	1.59	0.67	1.65	−0.21	1.09

$^{*}p = 0.05$; $^{**}p = 0.02$.

associated with the change toward a Class II canine relationship ($r = 0.42$, $p < 0.01$) and molar relationship ($r = 0.41$, $p < 0.001$) on the noncrossbite side. No such association was found on the crossbite side ($r = 0.11$ and 0.02, respectively, $p > 0.05$).

The maxillary arch was expanded significantly from T1 to T2. In addition, a spontaneous increase in mandibular intermolar width occurred ($p < 0.001$). No difference was found in mandibular intercanine width (Table IV).

Changes in Relative Condylar Position and Condylar Movement Versus Changes in Occlusion

Change in relative condylar position was associated with change in canine ($r = 0.52$) and molar ($r = 0.50$) relationship on the noncrossbite side ($p < 0.05$). No such association was found on the crossbite side ($r = 0.19$ and 0.36, respectively, $p > 0.05$). Horizontal movement of the condyle was not associated with change in canine or molar relationship on either side ($r = 0.39$ and 0.35 on

Table IV. Maxillary and mandibular intercanine (C-C) and intermolar (6-6) width before (T1) and after (T2) as well as change from before to after (T2-T1) treatment of functional posterior crossbite in the deciduous and mixed dentitions

	Arch width					
	T1		*T2*		*T2-T1*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Max. C-C (n = 58) (mm)	28.21	2.37	32.99	2.36	4.78	1.90***
Max. 6-6 (n = 60) (mm)	35.98	3.23	40.84	3.42	4.86	1.63***
Man. C-C (n = 58) (mm)	25.86	1.83	25.71	1.90	−0.15	0.75
Man. 6-6 (n = 60) (mm)	34.50	3.72	35.14	3.25	0.64	0.90***

*** $p < 0.001$.

the noncrossbite and 0.18 and 0.00 on the crossbite side, respectively, $p > 0.05$). Midline deviation was not associated with any parameter for change in condylar position from T1 to T2 ($p > 0.05$).

DISCUSSION

In keeping with previous studies, we showed that children with unilateral posterior crossbite resulting from lateral functional shift into maximum intercuspation have asymmetric condylar position in centric occlusion.[9-11] We could confirm that the asymmetry was due to an anterior and inferior position within the glenoid fossa of the noncrossbite side condyle compared with that of the crossbite side.[9-11] The crossbite side condyle was found to be in a relatively normal position.[11] We could also confirm the obvious assumption that patients with functional posterior crossbite shift into asymmetric occlusal relationships.

Our data confirm that elimination of a lateral functional mandibular shift through maxillary expansion results in a more symmetric condylar position.[9] Previously, this change was documented with transcranial radiographs,[9] which may not allow accurate description of individual changes in condylar position.[16,28] We found that the mechanism for achieving posttreatment symmetry was primarily due to posterior and superior movement of the condyle on the noncrossbite side condyle. This conclusion was based on evaluation of changes in joint space measurements, as well as measurements of condylar movement on tomograms superimposed on the outline of the glenoid fossa. Concomitant with this change toward a more symmetric condylar position, the posterior joint space was reduced approximately four times more than the anterior joint space increased. This may be explained by the conic shape of the glenoid fossa, as well as the difference in slope of the anterior and posterior borders. As the condyle slides on the articular eminence, anterior joint space remains constant, probably determined by the thickness of the articular disk, while posterior and superior joint space change. Neither measurement technique disclosed any change in condylar position on the crossbite side, most likely due to the greater proximity of this condyle to the center of rotation of the mandibular movement.

The occlusion changed toward greater symmetry. The midline deviation reduced approximately 75% with elimination of the functional shift, and a bilateral symmetry in canine and molar relationship was established. However, contrary to expectations, the actual change in molar and canine relationship was significant only on the crossbite side (Table III). Regarding molar relationship, one likely explanation may be the observed mesiobuccal rotation of the maxillary first molars, which took place with the Quad Helix appliance, exaggerating the change in molar relationship on the crossbite side and reducing the change on the noncrossbite side. Any mesial eruption of the lower first molars and closure of residual primate spacing would also have a similar effect. Distal movement of the maxillary canines concomitant with maxillary expansion would similarly affect the measured canine relationship.

Although our statistical analysis failed to disclose any anteroposterior asymmetry in condylar position at T2, evaluation of actual mean values indicates that perfect symmetry was not achieved (Table I) with the noncrossbite side condyle being slightly more posterior than that on the crossbite side. This could be explained by compensatory resorption of the articular eminence on the noncrossbite side before correction of the functional crossbite. Such resorption would tend to increase the anterior joint space and thereby contribute to a more posterior relative condylar position after treatment. This theory may be supported by the observation that patients with unilateral posterior crossbite have a less steep condylar path on the noncrossbite than on the crossbite side.[25] Another possible reason for this slight asymmetry is a relative anterior translation of the temporal bone by anteriorly directed forces from the distracted noncrossbite side condyle. These changes are probably progressive and would increase with the length of time the functional shift is present. Our sample was not large enough to analyze such associations. Explanation of the significant difference in superior joint space after treatment is more difficult. Compensatory eruption of the posterior teeth on the crossbite side before treatment may result in initial tooth contact on this side, necessitating additional mandibular closure on the noncrossbite side to achieve maximum intercuspation. Differences in contact relationship on the noncrossbite side could have a similar effect. Such subtle changes may not be associated with a clinically detectable shift. It should be stressed that some degree of condylar or occlusal asymmetry may be considered normal. Several authors have documented asymmetry in condyle and fossa structure,[29] as well as right and left differences in condylar position,[27,40-32] in asymptomatic adult samples. The initial midline deviation was also not fully corrected in our sample. Any residual component of mandibular shift due to occlusal interferences, asymmetric activity in the muscles of mastication,[33-35] or anterior dental asymmetries due to crowding could account for this.

Several authors have documented autonomous increases in mandibular arch width and buccal tipping of the mandibular posterior teeth concomitant with maxillary expansion.[17,20] This association has been attributed to alterations in occlusion, providing lateral forces as cuspal contacts move from the fossa of opposing teeth to cuspal inclines[17,19,20] and to widening of the area of attachment of the buccal musculature, altering the balance with tongue pressure.[17] Our study confirms that maxillary expansion is associated with autonomous increase in mandibular molar width ($p < 0.001$). However, part of the expansion may be explained by normal developmental changes.[36] The lack of increase in mandibular intercanine width may be explained by elimination of labial pressure from the maxillary canines after elimination of interferences concomitant with correction of the posterior crossbite. Overall, the changes in arch width that accompanied maxillary expansion were small and may be considered clinically insignificant.

Our results and inferences from previous studies support two primary reasons for early treatment of functional posterior crossbite. First, self-correction does not occur frequently enough to justify a delay in treatment,[1,8] and correction in the deciduous or early mixed dentition greatly increases the probability of the permanent molars and premolars erupting into normal transverse relationship.[1,14,22] Second, the asymmetric condylar position may predispose to progressive asymmetric compensation of the condyle-fossa relationship, resulting in craniofacial asymmetry[23-25,35] and increased risk of temporomandibular disorders.[24,25,37,38] Several authors have shown an increase in electromyographic activity of the muscles of mastication on the crossbite side in children with functional mandibular shifts.[33-35] According to the functional matrix theory, alterations of the muscular pattern may affect the structure of the developing mandible.

Tomographic evaluation of change in condylar position has limitations because variations in depth of the cut and angulation of the radiation beam may cause dramatic changes in the apparent structure of the condyle and fossa as well as the relative position of the condyle within the fossa. This is primarily due to the bipolar structure and medial angulation of the condyle. In part of our sample, SMV radiographs were used to orient the beam according to the angulation of the condylar head in relation to the cranial base. In a few cases, however, a standard correction angle was used to reduce the overall radiation exposure, probably with minor risk of bias.[27] We made all attempts to select pretreatment and posttreatment tomograms of similar depth of cut, to minimize bias due to the documented variation in condylar position between adjacent tomographic sections.[27,39] Also, the fact that all tomograms were made in the same radiographic facility maximized consistency in positioning of the patient and in orientation of the radiation beam at both time periods in our study. Superimposing the pretreatment and posttreatment tomographic images on the best fit of the fossa allowed direct interpretation of positional and rotational changes of the condyles. This was to verify the interpretation of condylar position through joint space analysis. Any variation in condylar structure could affect the joint space measurements, because slightly different parts of the condyle were in closest proximity to the fossa at the two time periods. However, both techniques gave similar results, both having clinically acceptable accuracy in describing condylar movement.

CONCLUSIONS

Children with functional unilateral posterior crossbite are characterized by:

1. An asymmetric pretreatment condylar position with the noncrossbite side condyle in an anterior and inferior position in the glenoid fossa.
2. An asymmetric pretreatment molar and canine relationship with a more Class II relationship on the crossbite side and a less Class II relationship on the noncrossbite side, concomitant with a midline deviation toward the crossbite side.
3. Establishment of more symmetric occlusal and condylar relationship after maxillary expansion through elimination of the crossbite and shift.
4. Establishment of more symmetry through posterior and superior movement of the noncrossbite side condyle and only minimal anterior and inferior movement of the crossbite side condyle.
5. A small amount of autonomous mandibular intermolar expansion concomitant with the maxillary expansion.

On the basis of these and other findings, it may be hypothesized that early treatment of unilateral functional posterior crossbite reduces the possibility of development of permanent skeletal asymmetry and dentoalveolar compensations.

REFERENCES

1. Kutin G, Hawes RR. Posterior crossbites in the deciduous and mixed dentitions. Am J Orthod 1969;56:491-504.
2. Day AJ, Foster TD. An investigation into the prevalence of molar crossbite and some associated aetiological conditions. Dent Pract 1971;21:402-10.
3. Infante PF. An epidemiologic study of finger habits in preschool children, as related to malocclusion, socioeconomic status, race, sex, and size of community. J Dent Child 1976;1:33-8.
4. de Vis H, de Boever JA, van Cauwenberghe P. Epidemiologic survey of functional conditions of the masticatory system in Belgian children aged 3-6 years. Comm Dent Oral Epidemiol 1984;12:203-7.
5. Heikinheimo K, Salmi K. Need for orthodontic intervention in five-year-old Finnish children. Proc Finn Dent Soc 1987;83:165-9.
6. Hannuksela A, Laurin A, Lehmus V, Kouri R. Treatment of crossbite in early mixed dentition. Proc Finn Dent Soc 1988;84:175-82.
7. Kurol J, Berglund L. Longitudinal study and cost-benefit analysis of the effect of early treatment of posterior cross-bites in the primary dentition. Eur J Orthod 1992;14:173-9.
8. Thilander B, Wahlund S, Lennartsson B. The effect of early interceptive treatment in children with posterior crossbite. Eur J Orthod 1984;6:25-34.
9. Myers DR, Barenie JT, Bell RA, Williamson EH. Condylar position in children with functional posterior crossbites: before and after crossbite correction. Pediatr Dent 1980;2:190-4.
10. Thornton MH, Pullinger AG, Turley PK. Dental and facial characteristics associated with unilateral posterior crossbite in the permanent dentition [Thesis]. Los Angeles: University of California, School of Dentistry, 1985.
11. Yoshikane TT, Pullinger AG, Turley PK. Characteristics of functional posterior crossbites in the deciduous and mixed dentitions [Thesis]. Los Angeles: University of California, School of Dentistry, 1987.
12. Harberson VA, Myers DR. Midpalatal suture opening during functional posterior crossbite correction. Am J Orthod 1978;74:310-3.
13. King DL. Functional posterior crossbite in the deciduous and early mixed dentition. Gen Dent 1978;1:36-40.
14. Schröder U, Schröder I. Early treatment of unilateral posterior crossbite in children with bilaterally contracted maxillae. Eur J Orthod 1984;6:65-9.
15. Lindner A, Henrikson CO, Odenrick L, Modéer T. Maxillary expansion of unilateral cross-bite in preschool children. Scand J Dent Res 1986;94:411-8.
16. Mongini F. The importance of radiography in the diagnosis of TMJ dysfunctions: a comparative evaluation of transcranial radiographs and serial tomography. J Prosthet Dent 1981;45:186-98.
17. Haas AJ. Gross reactions to the widening of the maxillary dental arch of the pig by splitting the hard palate. Am J Orthod 1959;45:868-9.
18. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. Angle Orthod 1961;31:73-90.
19. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod 1970;58:41-66.
20. Gryson JA. Changes in mandibular interdental distance concurrent with rapid maxillary expansion. Angle Orthod 1977;47:186-92.
21. Lindner A. Longitudinal study on the effect of early interceptive treatment in 4-year-old children with unilateral cross-bite. Scand J Dent Res 1989;97:432-8.
22. Purcell PD. Effectiveness of posterior crossbite correction during the mixed dentition. J Pedodont 1985;9:302-11.
23. O'Byrn B, Sadowsky C, Schneider B, BeGole E. An evaluation of mandibular asymmetry in adults with unilateral posterior crossbite. Am J Orthod Dentofac Orthop 1995;107:394-400.
24. Kantomaa T. The shape of the glenoid fossa affects the growth of the mandible. Eur J Orthod 1988;10:249-54.
25. Pirttiniemi P, Kantomaa T, Lahtela P. Relationship between craniofacial and condyle path asymmetry in unilateral cross-bite patients. Eur J Orthod 1990;12:408-13.
26. Dahlberg G. Statistical methods for medical and biological students. London: George Allen and Unwin Ltd, 1940:122-32.
27. Pullinger A, Hollender L, Solberg WK, Petersson A. A tomographic study of mandibular condyle position in an asymptomatic population. J Prosthet Dent 1985;53:706-13.
28. Pullinger AG, Hollender L. Assessment of mandibular condyle position: a comparison of transcranial radiographs and linear tomograms. Oral Surg Oral Med Oral Pathol 1985;60:329-34.
29. Weinberg LA. An evaluation of asymmetry in TMJ radiographs. J Prosthet Dent 1978;40:315-23.
30. Weinberg LA. Correlation of temporomandibular dysfunction with radiographic findings. J Prosthet Dent 1972;28:519-39.
31. Blaschke DD, Blaschke TJ. Normal TMJ bony relationships in centric occlusion. J Dent Res 1981;60:98-104.
32. Williams BH. Oriented lateral temporomandibular joint laminagraphs: symptomatic and nonsymptomatic joints compared. Angle Orthod 1983;53:228-36.
33. Troelstrup B, Møller E. Electromyography of the temporalis and masseter muscles in children with unilateral cross-bite. Scand J Dent Res 1970;78:425-30.
34. Ingervall B, Thilander B. Activity of temporal and masseter muscles in children with a lateral forced bite. Angle Orthod 1975;45:249-58.
35. Thilander B. Temporomandibular joint problems in children. In: Carlson DS, McNamara JA, Ribbens KA, editors. Monograph 16, Craniofacial growth series. Ann Arbor: Center for Human Growth and Development, The University of Michigan, 1985:89-104.
36. Moyers CTA. The dentition of the growing child. Cambridge: Harvard University Press, 1959.
37. Egermark-Eriksson I. Malocclusion and some functional recordings of the masticatory system in Swedish school children. Swed Dent J 1982;6:9-20.
38. Egermark-Eriksson I, Carlsson GE, Magnusson T, Thilander B. A longitudinal study on malocclusion in relation to signs and symptoms of cranio-mandibular disorders in children and adolescents. Eur J Orthod 1990;12:399-407.
39. Pullinger AG, Hollender L. Variation in condyle-fossa relationships according to different methods of evaluation in tomograms. Oral Surg Oral Med Oral Pathol 1986;62:719-27.

The medical necessity narrative must be signed and dated by the requesting provider and submitted on the office letterhead of the provider. If applicable, any supporting documentation from the other involved clinician(s) must also be signed and dated by such clinician(s), and appear on office letterhead of such clinician(s). The requesting provider is responsible for coordinating with the other involved clinician(s) and is responsible for compiling and submitting any supporting documentation furnished by other involved clinician(s) along with the medical necessity narrative.

Attestation

I certify under the pains and penalties of perjury that I am the prescribing provider identified on this form. Any attached statement on my letterhead has been reviewed and signed by me. I certify that the medical necessity information (per 130 CMR 450.204) on this form is true, accurate, and complete, to the best of my knowledge. I understand that I may be subject to civil penalties or criminal prosecution for any falsification, omission, or concealment of any material fact contained herein.

Prescribing provider's signature: ____
(Signature and date stamps, or the signature of anyone other than the provider, are not acceptable.)

Printed name of prescribing provider________________________ Date ______________________

450.202: Nondiscrimination

(A) M.G.L. c. 151B, § 4, clause 10 prohibits discrimination against any individual who is a recipient of federal, state, or local public assistance, including MassHealth, because the individual is such a recipient or because of any requirement of such an assistance program. Accordingly, except as specifically permitted or required by law, no provider may deny any medical service to a member eligible for such service unless the provider would, at the same time and under similar circumstances, deny the same service to a patient who is not a MassHealth member (for example, no new patients are being accepted, or the provider does not provide the desired service to any patient). A provider may not specify a particular setting for the provision of services to a member that is not also specified for nonmembers in similar circumstances.

(B) No provider may engage in any practice, with respect to any member, that constitutes unlawful discrimination under any other state or federal law or regulation, including, but not limited to, practices that violate the provisions of Section 1557 of the Affordable Care Act prohibiting discrimination on the basis of race, color, national origin, sex (including pregnancy, gender identity and sex stereotyping), age, or disability; Title VI of the Civil Rights Act of 1964; Title IX of the Education Amendments of 1972; Section 504 of the Rehabilitation Act of 1973; and the Age Discrimination Act of 1975.

(C) Pursuant to 42 U.S.C. 1396u-2 and 42 CFR 438.3(d), MCOs, Accountable Care Partnership Plans, Primary Care ACO's participating primary care providers (participating PCPs), PCCs, the behavioral health contractor, SCOs, and ICOs may not unlawfully discriminate and will not use any policy or practice that has the effect of unlawfully discriminating against a MassHealth member eligible to enroll in the contractor's MassHealth plan on the basis of health status, need for health-care services, race, color, national origin, sex, sexual orientation, gender identity, or disability. MCOs, Accountable Care Partnership Plans, Primary Care ACO's participating primary care providers (participating PCPs), PCCs, the behavioral health contractor, SCOs, and ICOs will accept for enrollment and reenrollment all members referred by the MassHealth agency in the order in which they are referred without restriction, provided that PCCs and participating PCPs will accept members for enrollment and reenrollment up to the limits for PCC panel capacity set under the contract between EOHHS and PCCs and the limits for participating PCP panel capacity set under the contract between EOHHS and participating PCPs.

(D) Violations of 130 CMR 450.202(A), (B), and (C) may result in administrative action, referral to the Massachusetts Commission Against Discrimination, or referral to the U.S. Department of Health and Human Services, or any combination of these.

450.203: Payment in Full

(A) Federal and state laws require that participation in MassHealth be limited to providers who agree to accept, as payment in full, the amounts paid in accordance with the applicable fees and rates or amounts established under a provider contract or regulations applicable to MassHealth payment. (*See* 42 CFR 447.15 and M.G.L. c. 118E, § 36.) No provider may solicit, charge, receive, or accept any money, gift, or other consideration from a member, or from any other person, for any item or medical service for which payment is available under MassHealth, in addition to, instead of, or as an advance or deposit against the amounts paid or payable by the MassHealth agency for such item or service, except to the extent that the MassHealth regulations specifically require or permit contribution or supplementation by the member or by a health insurer.

(B) If the provider receives payment from a member for any service payable under MassHealth without knowing that the member was a MassHealth member at the time the service was provided, the provider must, upon learning that the individual is a MassHealth member, immediately return all sums solicited, charged, received, or accepted with respect to such service.

450.204: Medical Necessity

The MassHealth agency does not pay a provider for services that are not medically necessary and may impose sanctions on a provider for providing or prescribing a service or for admitting a member to an inpatient facility where such service or admission is not medically necessary.

450.204: continued

(A) A service is medically necessary if

(1) it is reasonably calculated to prevent, diagnose, prevent the worsening of, alleviate, correct, or cure conditions in the member that endanger life, cause suffering or pain, cause physical deformity or malfunction, threaten to cause or to aggravate a handicap, or result in illness or infirmity; and

(2) there is no other medical service or site of service, comparable in effect, available, and suitable for the member requesting the service, that is more conservative or less costly to the MassHealth agency. Services that are less costly to the MassHealth agency include, but are not limited to, health care reasonably known by the provider, or identified by the MassHealth agency pursuant to a prior-authorization request, to be available to the member through sources described in 130 CMR 450.317(C), 503.007: *Potential Sources of Health Care*, or 517.007: *Utilization of Potential Benefits*.

(B) Medically necessary services must be of a quality that meets professionally recognized standards of health care, and must be substantiated by records including evidence of such medical necessity and quality. A provider must make those records, including medical records, available to the MassHealth agency upon request. (*See* 42 U.S.C. 1396a(a)(30) and 42 CFR 440.230 and 440.260.)

(C) A provider's opinion or clinical determination that a service is not medically necessary does not constitute an action by the MassHealth agency.

(D) Additional requirements about the medical necessity of MassHealth services are contained in other MassHealth regulations and medical necessity and coverage guidelines.

(E) Any regulatory or contractual exclusion from payment of experimental or unproven services refers to any service for which there is insufficient authoritative evidence that such service is reasonably calculated to have the effect described in 130 CMR 450.204(A)(1).

450.205: Recordkeeping and Disclosure

(A) The MassHealth agency will not pay a provider for services if the provider does not have adequate documentation to substantiate the provision of services payable under MassHealth. All providers must keep such records, including medical records, as are necessary to disclose fully the extent and medical necessity of services provided to, or prescribed for, members and must provide to the MassHealth agency and the Attorney General's Medicaid Fraud Division, the State Auditor and the United States Department of Health and Human Services on request such information and any other information about payments claimed by the provider for providing services or otherwise described in 130 CMR 450.205. (*See e.g.*, 42 U.S.C. 1396a(a)(27).) All providers must also disclose such records and information to any other state and federal agency to which disclosure is required by law.

(B) All providers must maintain complete patient account records. Patient account records must include complete documentation of charges, indicate the date and amount of all debit and credit transactions, and support the appropriateness of the amounts billed and paid. Institutional providers must, in addition, provide on request all records maintained by or within the institution about services provided to members by other providers. Pharmacy providers must, in addition, keep photocopies of the temporary MassHealth cards referenced when filling prescriptions, if applicable, and must produce a copy of the card on request.

(C) A provider must maintain and disclose any and all financial, statistical, and other information as may be required by the MassHealth agency, the Center for Health Information and Analysis, or any other agency described in 130 CMR 450.205(A). The required information must include, but is not limited to, ownership and licensure information, cost reports, charge books, audited financial statements, financial records, federal and state tax returns, invoices, general ledgers, trial balances, remittance advices, and explanations of benefits from health insurers and managed care organizations. Such records and documents must be provided within the time period specified by the requesting agency.

MEDICAL NECESSITY STATUTE
(130 CMR 450.204 A & B)

A Service is medically necessary if:

(A) it is REASONABLY CALCULATED TO prevent, diagnose, prevent the worsening of, alleviate, correct, or cure conditions in the member THAT endanger life, cause suffering or pain, cause physical deformity or malfunction, threaten to cause or to aggravate a handicap, or result in illness or infirmity; AND (B) THERE IS NO OTHER MEDICAL SERVICE or site of service, comparable in effect, available, and suitable for the member requesting the service that is more conservative or less costly to the MassHealth agency.

STATUTE-BASED FLOW CHART (FOR THIS PATIENT)

Orthodontic services for Patient: **is Medically Necessary because:**

(A) THE SERVICE IS REASONABLY CALCULATED TO:

- [ ] Prevent a Condition
- [ ] Diagnose a Condition
- [ ] Prevent Worsening of a Condition
- [ ] Alleviate a Condition
- [ ] Correct a Condition
- [ ] Cure a Condition

THAT:

- [ ] Endangers Life
- [ ] Causes Suffering or pain
- [ ] Causes Physical Deformity
- [ ] Causes Malfunction
- [ ] Threatens to cause a handicap
- [ ] Threatens to aggravate a handicap
- [ ] Results in Illness
- [ ] Results in infirmity (Physical or Mental)

AND (B) THERE IS NO OTHER MEDICAL SERVICE:

- [X]
- [X] Available
- [X] Suitable
- [X] More Conservative or Less Costly

ORTHODONTIC FLOW CHART DETAILS (FOR THIS PATIENT)

HARMFUL CONDITION FOR THIS PATIENT

- [ ] Crowding (non-cleansable)
- [ ] Spacing (gingival food-impaction)
- [ ] Deep Impinging Overbite
- [ ] Open Bite
  - [ ] Anterior
  - [ ] Posterior
- [ ] Cross Bite (edge-to-edge included)
  - [ ] Anterior
  - [ ] Posterior
- [ ] Occlusal Trauma
  - [ ] Tooth Structure Trauma (#s)__________
  - [ ] Gingival Structure Trauma (#s)________
  - [ ] TMJ Trauma (i.e)________________
- [ ]
- [ ] Ectopic Tooth #________________
- [ ] Other Condition:______________

HARMFUL EFFECT FOR THIS PATIENT

- [ ] Causes Gum & Bone Infirmity
- [ ] Causes Tooth Infirmity
- [ ] Causes TMJ Infirmity
- [ ] Cause Emotional Infirmity
- [ ] Causes Pain At: ________________
- [ ] Causes Other Suffering

____

OTHER MEDICAL SERVICE OPTIONS?

- NO Comparable in effect
- NO Available
- NO Suitable
- NO More Conservative or Less Costly

Based on these checked off harmful conditions, harmful effects, and since there is no other medical service option, I am hereby certifying that this patient meets the threshold for coverage under The Medical Necessity Statute, which defines this service as Medically Necessary.

____

Dr. Mouhab Z. Rizkallah DDS CAGS MSD **DATE**

Form Date 11/21/2020