EISSN 2148-9505

Indexed in PubMed, Web of Science and Scopus

Turkish Orthodontic Society

TURKISH JOURNAL of ORTHODONTICS

Volume 33
Issue 03
September 2020

AVES

turkjorthod.org

TURKISH JOURNAL of
ORTHODONTICS

Publisher
İbrahim KARA

Publication Director
Ali ŞAHİN

Editorial Development
Gizem KAYAN TEKAÜT

Deputy Publication Director
Gökhan ÇİMEN

Publication Coordinators
İrem SOYSAL
Arzu YILDIRIM
Deniz KAYA
Bahar ALBAYRAK
Emre KARA

Finance and Administration
Zeynep YAKIŞIRER ÜREN
Betül ÇİMEN

Project Coordinators
Sinem Fehime KOZ
Doğan ORUÇ

Graphics Department
Ünal ÖZER
Deniz Elif DURAN
Beyzanur KARABULUT

Contact
Address: Büyükdere Cad. No: 105/9
34394 Mecidiyeköy, Şişli-İstanbul
Phone: +90 212 217 17 00
Fax: +90 212 217 22 92
E-mail: info@avesyayincilik.com

AVES turkjorthod.org

TURKISH JOURNAL of ORTHODONTICS

Aims and Scopes

Turkish Journal of Orthodontics (Turk J Orthod) is an international, scientific, open access periodical published in accordance with independent, unbiased, and double-blinded peer-review principles. The journal is the official publication of Turkish Orthodontic Society and it is published quarterly on March, June, September and December.

Turkish Journal of Orthodontics publishes clinical and experimental studies on on all aspects of orthodontics including craniofacial development and growth, reviews on current topics, case reports, editorial comments and letters to the editor that are prepared in accordance with the ethical guidelines. The journal's publication language is English and the Editorial Board encourages submissions from international authors.

Journal's target audience includes academicians, specialists, residents, and general practitioners working in the fields of orthodontics, dentistry, medicine and other related fields.

Turkish Journal of Orthodontics is currently indexed in PubMed Central, Web of Science-Emerging Sources Citation Index, Scopus and TÜBİTAK ULAKBİM TR Index.

The editorial and publication processes of the journal are shaped in accordance with the guidelines of the International Committee of Medical Journal Editors (ICMJE), World Association of Medical Editors (WAME), Council of Science Editors (CSE), Committee on Publication Ethics (COPE), European Association of Science Editors (EASE), and National Information Standards Organization (NISO). The journal is in conformity with the Principles of Transparency and Best Practice in Scholarly Publishing (doaj.org/bestpractice).

Processing and publication are free of charge with the journal. No fees are requested from the authors at any point throughout the evaluation and publication process. All manuscripts must be submitted via the online submission system, which is available at turkjorthod.org. The journal guidelines, technical information, and the required forms are available on the journal's web page.

All expenses of the journal are covered by the Turkish Orthodontic Society.

Statements or opinions expressed in the manuscripts published in the journal reflect the views of the author(s) and not the opinions of the Turkish Orthodontic Society, editors, editorial board, and/or publisher; the editors, editorial board, and publisher disclaim any responsibility or liability for such materials.

All published content is available online, free of charge at turkjorthod.org.

OPEN ACCESS

Editor in Chief: Derya Germeç Çakan
Address: Bağdat Cad. No: 238, Göztepe,34728 İstanbul/Turkey
Phone: +90 216 468 08 00
Fax: +90 216 468 08 00
E-mail: info@turkjorthod.org

Publisher: AVES
Address: Büyükdere Cad. 105/9 34394 Mecidiyeköy, Şişli, İstanbul, Turkey
Phone: +90 212 217 17 00
Fax: +90 212 217 22 92
E-mail: info@avesyayincilik.com
Web page: avesyayincilik.com

Instructions to Authors

Turkish Journal of Orthodontics (Turk J Orthod) is an international, scientific, open access periodical published in accordance with independent, unbiased, and double-blinded peer-review principles. The journal is the official publication of Turkish Orthodontic Society and it is published quarterly on March, June, September and December.

Turkish Journal of Orthodontics publishes clinical and experimental studies on on all aspects of orthodontics including craniofacial development and growth, reviews on current topics, case reports, editorial comments and letters to the editor that are prepared in accordance with the ethical guidelines. The journal's publication language is English and the Editorial Board encourages submissions from international authors.

The editorial and publication processes of the journal are shaped in accordance with the guidelines of the International Council of Medical Journal Editors (ICMJE), the World Association of Medical Editors (WAME), the Council of Science Editors (CSE), the Committee on Publication Ethics (COPE), the European Association of Science Editors (EASE), and National Information Standards Organization (NISO). The journal conforms to the Principles of Transparency and Best Practice in Scholarly Publishing (doaj.org/bestpractice).

Originality, high scientific quality, and citation potential are the most important criteria for a manuscript to be accepted for publication. Manuscripts submitted for evaluation should not have been previously presented or already published in an electronic or printed medium. The journal should be informed of manuscripts that have been submitted to another journal for evaluation and rejected for publication. The submission of previous reviewer reports will expedite the evaluation process. Manuscripts that have been presented in a meeting should be submitted with detailed information on the organization, including the name, date, and location of the organization.

Manuscripts submitted to Turkish Journal of Orthodontics will go through a double-blind peer-review process. Each submission will be reviewed by at least two external, independent peer reviewers who are experts in their fields in order to ensure an unbiased evaluation process. The editorial board will invite an external and independent editor to manage the evaluation processes of manuscripts submitted by editors or by the editorial board members of the journal. The Editor in Chief is the final authority in the decision-making process for all submissions.

An approval of research protocols by the Ethics Committee in accordance with international agreements (World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects," amended in October 2013, www.wma.net) is required for experimental, clinical, and drug studies and for some case reports. If required, ethics committee reports or an equivalent official document will be requested from the authors. For photographs that may reveal the identity of the patients, releases signed by the patient or their legal representative should be enclosed.

For manuscripts concerning experimental research on humans, a statement should be included that shows that written informed consent of patients and volunteers was obtained following a detailed explanation of the procedures that they may undergo. For studies carried out on animals, the measures taken to prevent pain and suffering of the animals should be stated clearly. Information on patient consent, the name of the ethics committee, and the ethics committee approval number should also be stated in the Materials and Methods section of the manuscript. It is the authors' responsibility to carefully protect the patients' anonymity. For photographs that may reveal the identity of the patients, authors are required to obtain publication consents from their patients or the parents/legal guardians of the patients. The publication approval form is available for download at turkjorthod.org. The form must be submitted during the initial submission.

All submissions are screened by a similarity detection software (iThenticate by CrossCheck).

In the event of alleged or suspected research misconduct, e.g., plagiarism, citation manipulation, and data falsification/fabrication, the Editorial Board will follow and act in accordance with COPE guidelines.

Each individual listed as an author should fulfill the authorship criteria recommended by the International Committee of Medical Journal Editors

(ICMJE - www.icmje.org). The ICMJE recommends that authorship be based on the following 4 criteria:

1. Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
2. Drafting the work or revising it critically for important intellectual content; AND
3. Final approval of the version to be published; AND
4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

In addition to being accountable for the parts of the work he/she has done, an author should be able to identify which co-authors are responsible for specific other parts of the work. In addition, authors should have confidence in the integrity of the contributions of their co-authors.

All those designated as authors should meet all four criteria for authorship, and all who meet the four criteria should be identified as authors. Those who do not meet all four criteria should be acknowledged in the title page of the manuscript.

Turkish Journal of Orthodontics requires corresponding authors to submit a signed and scanned version of the authorship contribution form (available for download through turkjorthod.org) during the initial submission process in order to act appropriately on authorship rights and to prevent ghost or honorary authorship. If the editorial board suspects a case of "gift authorship," the submission will be rejected without further review. As part of the submission of the manuscript, the corresponding author should also send a short statement declaring that he/she accepts to undertake all the responsibility for authorship during the submission and review stages of the manuscript.

Turkish Journal of Orthodontics requires and encourages the authors and the individuals involved in the evaluation process of submitted manuscripts to disclose any existing or potential conflicts of interests, including financial, consultant, and institutional, that might lead to potential bias or a conflict of interest. Any financial grants or other support received for a submitted study from individuals or institutions should be disclosed to the Editorial Board. To disclose a potential conflict of interest, the ICMJE Potential Conflict of Interest Disclosure Form should be filled in and submitted by all contributing authors. Cases of a potential conflict of interest of the editors, authors, or reviewers are resolved by the journal's Editorial Board within the scope of COPE and ICMJE guidelines.

The Editorial Board of the journal handles all appeal and complaint cases within the scope of COPE guidelines. In such cases, authors should get in direct contact with the editorial office regarding their appeals and complaints. When needed, an ombudsperson may be assigned to resolve cases that cannot be resolved internally. The Editor in Chief is the final authority in the decision-making process for all appeals and complaints.

When submitting a manuscript to Turkish Journal of Orthodontics, authors accept to assign the copyright of their manuscript to Turkish Orthodontic Society. If rejected for publication, the copyright of the manuscript will be assigned back to the authors. Turkish Journal of Orthodontics requires each submission to be accompanied by a Copyright Transfer Form (available for download at turkjorthod.org). When using previously published content, including figures, tables, or any other material in both print and electronic formats, authors must obtain permission from the copyright holder. Legal, financial and criminal liabilities in this regard belong to the author(s).

Statements or opinions expressed in the manuscripts published in Turkish Journal of Orthodontics reflect the views of the author(s) and not the opinions of the editors, the editorial board, or the publisher; the editors, the editorial board, and the publisher disclaim any responsibility or liability for such materials. The final responsibility in regard to the published content rests with the authors.

MANUSCRIPT PREPARATION

The manuscripts should be prepared in accordance with ICMJE-Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals (updated in December 2017 - http://www.icmje.org/icmje-recommendations.pdf). Authors are required to prepare manuscripts in accordance with the CONSORT guidelines for randomized research studies, STROBE guidelines for observational original research studies, STARD guidelines for studies on diagnostic accuracy, PRISMA guidelines for systematic reviews and meta-analysis, ARRIVE guidelines for experimental animal studies, and TREND guidelines for non-randomized public behavior.

Manuscripts can only be submitted through the journal's online manuscript submission and evaluation system, available at turkjorthod.org. Manuscripts submitted via any other medium will not be evaluated.

Manuscripts submitted to the journal will first go through a technical evaluation process where the editorial office staff will ensure that the manuscript has been prepared and submitted in accordance with the journal's guidelines. Submissions that do not conform to the journal's guidelines will be returned to the submitting author with technical correction requests.

Language

Submissions that do not meet the journal's language criteria may be returned to the authors for professional language editing. Authors whose manuscripts are returned due to the language inadequacy must resubmit their edited papers along with the language editing certificate to verify the quality. Editing services are paid for and arranged by authors, and the use of an editing service does not guarantee acceptance for publication.

Authors are required to submit the following:

- Copyright Transfer Form,
- Author Contributions Form, and
- ICMJE Potential Conflict of Interest Disclosure Form (should be filled in by all contributing authors)

during the initial submission. These forms are available for download at turkjorthod.org.

Preparation of the Manuscript

Title page: A separate title page should be submitted with all submissions and this page should include:

- The full title of the manuscript as well as a short title (running head) of no more than 50 characters,
- Name(s), affiliations, and highest academic degree(s) of the author(s),
- Grant information and detailed information on the other sources of support,
- Name, address, telephone (including the mobile phone number) and fax numbers, and email address of the corresponding author,
- Acknowledgment of the individuals who contributed to the preparation of the manuscript but who do not fulfill the authorship criteria.

Abstract: An abstract should be submitted with all submissions except for Letters to the Editor. The abstract of Original Articles should be structured with subheadings (Objective, Methods, Results, and Conclusion). Please check Table 1 below for word count specifications.
Keywords: Each submission must be accompanied by a minimum of three to a maximum of six keywords for subject indexing at the end of the abstract. The keywords should be listed in full without

abbreviations. The keywords should be selected from the National Library of Medicine, Medical Subject Headings database (https://www.nlm.nih.gov/mesh/MBrowser.html).

Manuscript Types

Original Articles: This is the most important type of article since it provides new information based on original research. The main text of original articles should be structured with Introduction, Methods, Results, Discussion, and Conclusion subheadings. Please check Table 1 for the limitations for Original Articles.

Statistical analysis to support conclusions is usually necessary. Statistical analyses must be conducted in accordance with international statistical reporting standards (Altman DG, Gore SM, Gardner MJ, Pocock SJ. Statistical guidelines for contributors to medical journals. Br Med J 1983: 7; 1489-93). Information on statistical analyses should be provided with a separate subheading under the Materials and Methods section and the statistical software that was used during the process must be specified.

Units should be prepared in accordance with the International System of Units (SI).

Editorial Comments: Editorial comments aim to provide a brief critical commentary by reviewers with expertise or with high reputation in the topic of the research article published in the journal. Authors are selected and invited by the journal to provide such comments. Abstract, Keywords, and Tables, Figures, Images, and other media are not included.

Review Articles: Reviews prepared by authors who have extensive knowledge on a particular field and whose scientific background has been translated into a high volume of publications with a high citation potential are welcomed. These authors may even be invited by the journal. Reviews should describe, discuss, and evaluate the current level of knowledge of a topic in clinical practice and should guide future studies. The main text should contain Introduction, Clinical and Research Consequences, and Conclusion sections. Please check Table 1 for the limitations for Review Articles.

Case Reports: There is limited space for case reports in the journal and reports on rare cases or conditions that constitute challenges in diagnosis and treatment, those offering new therapies or revealing knowledge not included in the literature, and interesting and educative case reports are accepted for publication. The text should include Introduction, Case Presentation, Discussion, and Conclusion subheadings. Please check Table 1 for the limitations for Case Reports.

Letters to the Editor: This type of manuscript discusses important parts, overlooked aspects, or lacking parts of a previously published article. Articles on subjects within the scope of the journal that might attract the readers' attention, particularly educative cases, may also be submitted in the form of a "Letter to the Editor." Readers can also present their comments on the published manuscripts in the form of a "Letter to the Editor." Abstract, Keywords, and Tables, Figures, Images, and other media should not be included. The text should be unstructured. The manuscript that is being commented on must be properly cited within this manuscript.

Table 1. Limitations for each manuscript type

TYPE OF MANUSCRIPT	WORD LIMIT	ABSTRACT WORD LIMIT	REFERENCE LIMIT	TABLE LIMIT	FIGURE LIMIT
ORIGINAL ARTICLE	4500	250 (Structured)	30	6	7 or total of 15 images
REVIEW ARTICLE	5000	250	50	6	10 or total of 20 images
CASE REPORT	1000	200	15	No tables	10 or total of 20 images
LETTER TO THE EDITOR	500	No abstract	5	No tables	No media

Tables

Tables should be included in the main document, presented after the reference list, and they should be numbered consecutively in the order they are referred to within the main text. A descriptive title must be placed above the tables. Abbreviations used in the tables should be defined below the tables by footnotes (even if they are defined within the main text). Tables should be created using the "insert table" command of the word processing software and they should be arranged clearly to provide easy reading. Data presented in the tables should not be a repetition of the data presented within the main text but should be supporting the main text.

Figures and Figure Legends

Figures, graphics, and photographs should be submitted as separate files (in TIFF or JPEG format) through the submission system. The files should not be embedded in a Word document or the main document. When there are figure subunits, the subunits should not be merged to form a single image. Each subunit should be submitted separately through the submission system. Images should not be labeled (a, b, c, etc.) to indicate figure subunits. Thick and thin arrows, arrowheads, stars, asterisks, and similar marks can be used on the images to support figure legends. Like the rest of the submission, the figures too should be blind. Any information within the images that may indicate an individual or institution should be blinded. The minimum resolution of each submitted figure should be 300 DPI. To prevent delays in the evaluation process, all submitted figures should be clear in resolution and large in size (minimum dimensions: 100 × 100 mm). Figure legends should be listed at the end of the main document.

Where necessary, authors should Identify teeth using the full name of the tooth or the FDI annotation.

All acronyms and abbreviations used in the manuscript should be defined at first use, both in the abstract and in the main text. The abbreviation should be provided in parentheses following the definition.

When a drug, product, hardware, or software program is mentioned within the main text, product information, including the name of the product, the producer of the product, and city and the country of the company (including the state if in USA), should be provided in parentheses in the following format: "Discovery St PET/CT scanner (General Electric, Milwaukee, WI, USA)"

All references, tables, and figures should be referred to within the main text, and they should be numbered consecutively in the order they are referred to within the main text.

Limitations, drawbacks, and the shortcomings of original articles should be mentioned in the Discussion section before the conclusion paragraph.

References

While citing publications, preference should be given to the latest, most up-to-date publications. If an ahead-of-print publication is cited, the DOI number should be provided. Authors are responsible for the accuracy of references. Journal titles should be abbreviated in accordance with the journal abbreviations in Index Medicus/MEDLINE/PubMed. When there are six or fewer authors, all authors should be listed. If there are seven or more authors, the first six authors should be listed followed by "et al." In the main text of the manuscript, references should be cited using Arabic numbers in parentheses. The reference styles for different types of publications are presented in the following examples.

Journal Article: Rankovic A, Rancic N, Jovanovic M, Ivanović M, Gajović O, Lazić Z, et al. Impact of imaging diagnostics on the budget – Are we spending too much? Vojnosanit Pregl 2013; 70: 709-11.

Book Section: Suh KN, Keystone JS. Malaria and babesiosis. Gorbach SL, Barlett JG, Blacklow NR, editors. Infectious Diseases. Philadelphia: Lippincott Williams; 2004.p.2290-308.

Books with a Single Author: Sweetman SC. Martindale the Complete Drug Reference. 34th ed. London: Pharmaceutical Press; 2005.

Editor(s) as Author: Huizing EH, de Groot JAM, editors. Functional reconstructive nasal surgery. Stuttgart-New York: Thieme; 2003.

Conference Proceedings: Bengisson S. Sothemin BG. Enforcement of data protection, privacy and security in medical informatics. In: Lun KC, Degoulet P, Piemme TE, Rienhoff O, editors. MEDINFO 92. Proceedings of the 7th World Congress on Medical Informatics; 1992 Sept 6-10; Geneva, Switzerland. Amsterdam: North-Holland; 1992. pp.1561-5.

Scientific or Technical Report: Cusick M, Chew EY, Hoogwerf B, Agrón E, Wu L, Lindley A, et al. Early Treatment Diabetic Retinopathy Study Research Group. Risk factors for renal replacement therapy in the Early Treatment Diabetic Retinopathy Study (ETDRS), Early Treatment Diabetic Retinopathy Study Kidney Int: 2004. Report No: 26.

Thesis: Yılmaz B. Ankara Üniversitesindeki Öğrencilerin Beslenme Durumları, Fiziksel Aktiviteleri ve Beden Kitle İndeksleri Kan Lipidleri Arasındaki Ilişkiler. H.Ü. Sağlık Bilimleri Enstitüsü, Doktora Tezi. 2007.

Manuscripts Accepted for Publication, Not Published Yet: Slots J. The microflora of black stain on human primary teeth. Scand J Dent Res. 1974.

Epub Ahead of Print Articles: Cai L, Yeh BM, Westphalen AC, Roberts JP, Wang ZJ. Adult living donor liver imaging. Diagn Interv Radiol. 2016 Feb 24. doi: 10.5152/dir.2016.15323. [Epub ahead of print].

Manuscripts Published in Electronic Format: Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis (serial online) 1995 Jan-Mar (cited 1996 June 5): 1(1): (24 screens). Available from: URL: http:/ www.cdc.gov/ncidodlEID/cid.htm.

REVISIONS

When submitting a revised version of a paper, the author must submit a detailed "Response to the reviewers" that states point by point how each issue raised by the reviewers has been covered and where it can be found (each reviewer's comment, followed by the author's reply and line numbers where the changes have been made) as well as an annotated copy of the main document. Revised manuscripts must be submitted within 30 days from the date of the decision letter. If the revised version of the manuscript is not submitted within the allocated time, the revision option may be canceled. If the submitting author(s) believe that additional time is required, they should request this extension before the initial 30-day period is over.

Accepted manuscripts are copy-edited for grammar, punctuation, and format. Once the publication process of a manuscript is completed, it is published online on the journal's webpage as an ahead-of-print publication before it is included in its scheduled issue. A PDF proof of the accepted manuscript is sent to the corresponding author and their publication approval is requested within 2 days of their receipt of the proof.

Editor in Chief: Derya Germeç Çakan
Address: Bağdat Cad. No: 238, Göztepe,34728 İstanbul/Turkey
Phone: +90 216 468 08 00
Fax: +90 216 468 08 00
E-mail: info@turkjorthod.org

Publisher: AVES
Address: Büyükdere Cad. 105/9 34394 Mecidiyeköy, Şişli, İstanbul, Turkey
Phone: +90 212 217 17 00
Fax: +90 212 217 22 92
E-mail: info@avesyayincilik.com
avesyayincilik.com

TURKISH JOURNAL of
ORTHODONTICS

Contents

Original Articles

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.20062

Original Article

Web-based Fully Automated Cephalometric Analysis: Comparisons between App-aided, Computerized, and Manual Tracings

Pamir Meriç[1], Julia Naoumova[2]

[1]Department of Orthodontics, Faculty of Dentistry, Trakya University, Edirne, Turkey
[2]Specialist Clinic of Orthodontics, Public Dental Service, Västra Götaland Region, Gothenburg, Sweden

Cite this article as: Meriç P, Naoumova J. Web-based Fully Automated Cephalometric Analysis: Comparisons between App-aided, Computerized, and Manual Tracings. Turk J Orthod 2020; 33(3): 142-9.

Main points:

- The fully automatic cephalometric analysis program CephX needs improvement to enhance its reliability for the majority of the dental measurements and for GoGn-SN (°).
- Manual correction of CephX gives similar results compared with CephNinja and Dolphin.
- CephX is significantly faster than CephNinja, Dolphin, and manual cephalometric analysis.

ABSTRACT

Objective: To compare the accuracy of cephalometric analyses made with fully automated tracings, computerized tracing, and app-aided tracings with equivalent hand-traced measurements, and to evaluate the tracing time for each cephalometric analysis method.

Methods: Pre-treatment lateral cephalometric radiographs of 40 patients were randomly selected. Eight angular and 4 linear parameters were measured by 1 operator using 3 methods: computerized tracing with software Dolphin Imaging 13.01(Dolphin Imaging and Management Solutions, Chatsworth, Calif, USA), app-aided tracing using the CephNinja 3.51 app (Cyncronus LLC, WA, USA) , and web-based fully automated tracing with CephX (ORCA Dental AI, Las Vegas, NV). Correction of CephX landmarks was also made. Manual tracings were performed by 3 operators. Remeasurement of 15 radiographs was carried out to determine the intra-examiner and inter-examiner (manual tracings) correlation coefficient (ICC). Inter-group comparisons were made with one-way analysis of variance. The Tukey test was used for post hoc testing.

Results: Overall, greater variability was found with CephX compared with the other methods. Differences in GoGn-SN (°), I-NA (°), I-NB (°), I-NA (mm), and I-NB (mm) were statistically ($p<0.05$) and clinically significant using CephX, whereas CephNinja and Dolphin were comparable to manual tracings. Correction of CephX landmarks gave similar results to CephNinja and Dolphin. All the ICCs exceeded 0.85, except for I-NA (°), I-NB (°), and I-NB (mm), which were traced with CephX. The shortest analyzing time was obtained with CephX.

Conclusion: Fully automatic analysis with CephX needs to be more reliable. However, CephX analysis with manual correction is promising for use in clinical practice because it is comparable to CephNinja and Dolphin, and the analyzing time is significantly shorter.

Keywords: Apps, artificial intelligence, automated identification, automatic tracing, cephalometric, computerized tracing, web-based

INTRODUCTION

Since its introduction in 1931, cephalometric analysis has become a widely used diagnostic and clinical tool in orthodontics (1). With the rapid advancement in technology, the manual method is gradually being replaced by digital cephalometric analysis software, which has numerous benefits, such as reduction in radiation doses, facilitated image acquisition, archiving and sharing, faster measurements, and easily determined treatment plans, as well as the elimination of chemical and associated environmental hazards. In addition, superimposition of serial radiographs can be performed faster, and it also allows the user to obtain several analyses at a time (2).

Address for Correspondence: Pamir Meriç, Department of Orthodontics, Faculty of Dentistry, Trakya University, Edirne, Turkey
E-mail: pamirmeric@trakya.edu.tr

Received: May 27, 2020
Accepted: July 16, 2020
Available Online Date: August 11, 2020

Specially designed medical and dental apps are one of the fastest growing categories of software, and as of today, more than 350 orthodontic apps exist, many of which can be accessed for free (3). Smartphones as an electronic training resource are useful for clinical decision support and to prevent medication errors (4); however, there is a lack of a systematic approach to evaluate the accuracy and evidence resulting from the use of mobile apps. There are contradictory findings regarding the validity of cephalometric analysis apps compared with the manual and digital tracing programs (5). The aspect that these digital tracing systems have in common, regardless of whether they are used on a tablet, smartphone, or a computer, is that the anatomical points need to be marked individually by the orthodontist during the tracing, making the cephalometric program only semiautomated. Since the main source of error in cephalometric analysis is landmark identification, it is important to assess whether the use of completely automated tracing programs, which have been developed lately, is reliable (6, 7). Computerized software and smartphone apps can save time compared with manual tracing (1, 8); however, physicians aim to use even lesser time for tracing. This might be possible with fully automated cephalometric analysis methods, such as web-based CephX, which is an artificial-intelligence (AI)–based algorithm that performs automatic, immediate cephalometric analyses (9). Automatic cephalometric analysis has been a topic of interest during the past years; however, the software algorithms developed did not seem accurate enough for clinical purposes. Whether a digital smartphone app or automatic analysis is selected, it should be precise, reliable, and highly reproducible. Given the increasing number of apps and computer-assisted cephalometric tracing programs and the lack of accuracy of the commercially available software, there is a need for comparative studies to allow the physicians to make an informed choice of suitable software and analysis methods (5, 10).

To our knowledge, there are no published data comparing all the 4 systems: fully automated, computerized, app-aided, and manual tracing. Therefore, this study aimed to compare the accuracy of manual cephalometric analyses to cephalometric analysis using AI, computerized method, and app-aided systems. In addition, the time required to perform the analysis using the 4 different methods was also assessed. The null hypothesis was that there are no statistical differences among the cephalometric analysis methods regarding the accuracy and the tracing time.

METHODS

The study was conducted according to the principles of the Declaration of Helsinki and was approved by the Research Ethics Committee at Trakya University, Faculty of Medicine (Approval No: TÜTF-BAEK 2017/318). Written informed consent was obtained from all the participants before their enrollment.

According to the power analysis, a minimum of 39 patients were needed to detect the correlations deviating from 0.5°/mm and above between the groups (with a significance level of 0.05 and power of 80%). The effect size was based on a previous study (11).

Pre-treatment lateral cephalometric radiographs of 40 patients (7 males, 33 females, mean age: 16.0 ± 4.6 years) were randomly selected from the archive of the Trakya University, Faculty of Dentistry, Department of Orthodontics. The cephalometric images were taken with the patient in the upright standing position with the Frankfort plane parallel to the floor, keeping the teeth in centric relation and the lips relaxed. All the lateral cephalometric radiographs were taken using the same cephalometric radiography machine (PaX-Flex; Vatech Inc. NJ) by the same technician with a magnification factor of 1.1.

The exclusion criteria were poor quality of cephalograms with artifacts that could interfere with the anatomical point identification, no unerupted or partially erupted teeth preventing incisor apex identification, and craniofacial deformities.

To optimize landmark identification, the same operator (PM) undertook all the digital and manual tracings, and to obtain a "manual ground truth," 2 additional manual operators were included; thus, a total of 3 observers performed the manual tracings. The mean measurements of the 3 observers represented the "manual ground truth."

No more than 5 tracings were made at a time to avoid operator fatigue. The same 8 angular and 4 linear parameters were measured on each radiograph (Figure 1, Table 1) except for the GoGn-SN value because CephX uses the GoMe plane to calculate the GoGn-SN angle.

To determine the intra-operator error, 15 radiographs were retraced digitally by the same operator (PM) after an interval of 1 month. For the intra-operator error of the "manual truth," 15

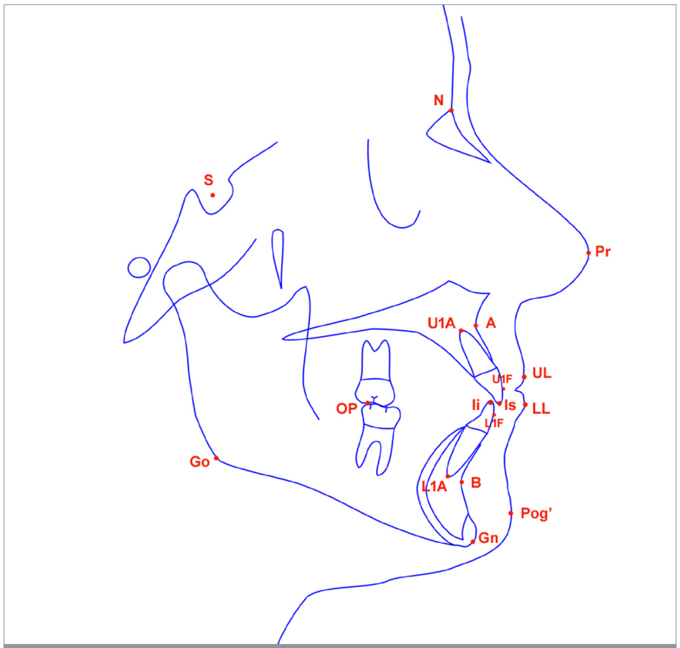

Figure 1. Cephalometric landmarks used in the study

S: Sella; N: Nasion; A: Point A; B: Point B; Go: Gonion; Gn: Gnathion; Pog: Soft tissue pogonion; Pr: Pronasale; UL: Upper lip; LL: lower lip; U1A: Upper incisor root apex; Is: Incision superior; Ii: Incision inferior; U1F: Upper incisor labial face; L1F: Lower incisor labial face radiographs were retraced by the 3 observers and the mean formed the "manual truth" values.

Analyzing time for each analysis was measured in seconds using a stopwatch. The start- and end-points for the manual cephalometric measurements included plotting of the landmarks and measuring the angles and distances. The manual measurements were made by 3 operators, and the mean analyzing time was calculated. Analyzing time for computerized and app-aided tracing included plotting of the landmarks by 1 operator as measurements of angles and distances were performed by the software. For the web-based fully automated tracing, the analyzing time was the time it took for the system to automatically identify the anatomical points. Manual correction of the landmark positions was also made, which was added to the total analyzing time. Calibration of the images for all the systems was also included in the analyzing time.

Table 1. Description of the cephalometric landmarks and measurements used in the study

LANDMARK	DESCRIPTION
Sella (S)	The center of sella turcica
Nasion (N)	The most anterior point of the frontonasal suture
Point A (A)	The innermost point on the contour of the maxilla between the anterior nasal spine and the alveolar crest
Point B (B)	The most posterior point in the concavity along the anterior border of the symphysis
Gonion (Go)	The most prominent point on the angle of the mandible formed by the junction of the ramus and the body of the mandible
Gnathion (Gn)	Midpoint between menton and pogonion
Pog'	Soft tissue pogonion
Pronasale (Pr)	Tip of the nose
Upper lip (UL)	Most anterior point of the upper lip
Lower lip (LL)	Most anterior point of the lower lip
Incision superior incisal (Is)	The midpoint of the incisal edge of the most prominent maxillary central incisor
Incision inferior (Ii)	The midpoint of the incisal edge of the most prominent mandibular central incisor
U1F	Most anterior point of the maxillary central incisor
L1F	Most anterior point of the mandibular central incisor
SNA (°)	Angle determined by points S, N, and A
SNB (°)	Angle determined by points S, N, and B
ANB (°)	Angle determined by points A, N, and B
I-I (°)	Angle formed by the intersection of the upper incisor axis and the lower incisor axis
I-NA (°)	Angle formed by the intersection of the upper incisor axis and the NA line
I-NA (mm)	Linear distance between the most anterior point of the maxillary central incisor (U1F) and the NA line
I-NB (°)	Angle formed by the intersection of the lower incisor axis and the NB line
I-NB (mm)	Linear distance between the most anterior point of the mandibular central incisor (L1F) and the NB line
Occlusal Plane	The line joining the distal occlusal contact point of the first molars to midway of the anterior overbite
GoMe plane	A line between gonion and menton
OCC-SN (°)	Angle between the SN line and the occlusal plane
GoGn-SN (°)	Angle between the Go-Gn and SN lines
E-line	Esthetic line joining the soft tissue pogonion and pronasale
UL E-line (mm)	Linear distance between the most anterior point of the upper lip (UL) and the E-Line
LL E-line (mm)	Linear distance between the most anterior point of the lower lip (LL) and the E-Line

Manual Tracing

For manual tracing, digital images imported to Adobe Photoshop 7.0 (Adobe Systems, San Jose, California, USA) and resized to scale 1:1 were printed. Using the rectangular marquee tool, a distance of 10 mm was measured on the vertical calibration ruler on the cephalogram. The selected area was copied and pasted into a new file. The amount of vertical pixels of the created file was noted. After returning to the original file, the image menu-image size tab was entered. Resample image box was unchecked, the amount of vertical pixels recorded from the previous image was written in the resolution box (pixels/cm), and the image was scaled.

The image properties of the film were 2.232×2.304 pixels, 150 dpi, and 8 bits. Manual tracing was performed on the printed image using a 0.35-mm lead pencil. All the hard tissue and soft tissue landmarks were traced, and double images were centered to form a single landmark. A ruler and protractor were used to measure the angular and linear parameters.

Computerized Tracing

For the computerized tracing method, digital radiographs saved as .jpeg files were imported to the Dolphin Imaging 13.01 software (Dolphin Imaging and Management Solutions, Chatsworth, Calif, USA). The files were in grayscale format, and the image properties of the film were 2.232×2.304 pixels, 150 dpi, and 8 bits. The digital films were calibrated by digitizing 2 points (20 mm) on the ruler within the digital cassette. Landmark identification was carried out manually using a mouse-driven cursor. The screen used for computerized analysis was 21.5" in size. All measurements were performed automatically by the software (Figure 2).

App-aided Tracing

For the app tracing method, the CephNinja 3.51 app (Cyncronus LLC, WA, USA) was used. All the digital radiographs were uploaded as .jpeg files to Microsoft OneDrive using a standard computer. The files were in grayscale format, and the image properties of the film were 2.232×2.304 pixels, 150 dpi, and 8 bits. The radiographs were

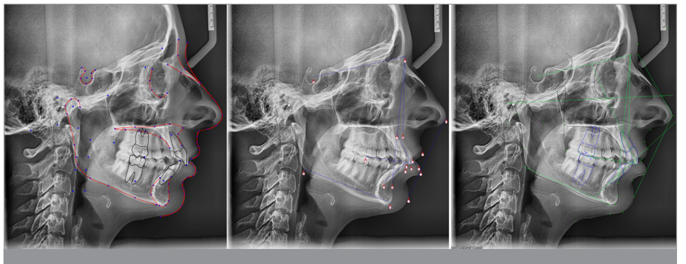

Figure 2. The same cephalometric radiograph traced with CephX (left), CephNinja (midmost) and Dolphin (right)

Table 2. Intra-class correlation coefficient (ICC) for reproducibility of each cephalometric analysis method

	CephX (cx)		CephX corrected (cxc)		CephNinja (cn)		Dolphin (d)		Manual (m) "ground truth"	
Measurements	**ICC**	**95%**	**ICC**	**95%**	**ICC**	**95%**	**ICC**	**95%**	**ICC**	**95%**
SKELETAL										
SNA (°)	0.965	0.902-0.988	0.914	0.768-0.970	0.893	0.713-0.963	0.940	0.833-0.979	0.973	0.913-0.991
SNB (°)	0.992	0.976-0.997	0.989	0.967-0.996	0.988	0.965-0.996	0.990	0.972-0.997	0.993	0.979-0.998
ANB (°)	0.983	0.949-0.995	0.977	0.935-0.992	0.988	0.964-0.996	0.975	0.902-0.992	0.992	0.976-0.997
GoGn-SN/GoMe-SN (°)	0.990	0.971-0.997	0.993	0.979-0.998	0.977	0.936-0.992	0.974	0.922-0.991	0.992	0.975-0.997
DENTAL										
I-NA (°)	0.750	0.409-0.908	0.838	0.594-0.942	0.964	0.898-0.988	0.970	0.916-0.990	0.985	0.955-0.995
I-NA (mm)	0.912	0.289-0.979	0.862	0.645-0.951	0.923	0.792-0.973	0.950	0.858-0.983	0.864	0.610-0.954
I-NB (°)	0.733	0.063-0.921	0.906	0.705-0.969	0.974	0.926-0.991	0.980	0.932-0.993	0.977	0.932-0.992
I-NB (mm)	0.824	0.436-0.943	0.947	0.853-0.982	0.969	0.911-0.989	0.982	0.943-0.994	0.950	0.857-0.983
I-I (°)	0.872	0.646-0.956	0.948	0.854-0.982	0.980	0.943-0.993	0.985	0.956-0.995	0.983	0.950-0.994
OCC-SN (°)	0.936	0.823-0.978	0.948	0.854-0.982	0.884	0.697-0.959	0.938	0.829-0.979	0.993	0.979-0.998
SOFT TISSUE										
UL E-line (mm)	0.890	0.553-0.967	0.968	0.557-0.993	0.988	0.963-0.996	0.987	0.963-0.996	0.996	0.976-0.997
LL E-line (mm)	0.990	0.973-0.997	0.991	0.974-0.997	0.987	0.962-0.995	0.993	0.981-0.998	0.993	0.981-0.998

(For the manual measurements, the "ground truth" values were used as the mean remeasurements of the 3 examiners)

Table 3. Intra-class correlation coefficient calculated for inter-examiner reliability of the manual tracings of 3 examiners

	Manual (m)	
Measurements	**ICC**	**95%**
SKELETAL		
SNA (°)	0.930	0.849 -0.965
SNB (°)	0.936	0.720 -0.976
ANB (°)	0.934	0.850-0.968
GoGn-SN (°)	0.950	0.824-0.980
DENTAL		
I-NA (°)	0.939	0.895-0.966
I-NA (mm)	0.900	0.830-0.944
I-NB (°)	0.980	0.966-0.989
I-NB (mm)	0.912	0.748-0.962
I-I (°)	0.928	0.878-0.959
OCC-SN (°)	0.931	0.881-0.962
SOFT TISSUE		
UL E-line (mm)	0.980	0.947-0.991
LL E-line (mm)	0.977	0.962-0.987

imported to the CephNinja app using an iPhone 6S (IOS 11.4) smartphone. The same calibration procedure (20 mm) was performed for the cephalometric films. Landmark identification was carried out manually on a smartphone screen using the index finger. The zoom-in/zoom-out function was used when needed (Figure 2).

Web-based Fully Automated Tracing

An online automatic cephalometric tracing and analysis service named CephX (ORCA Dental AI, Las Vegas, NV) was used. After entering the system with www.cephx.com, using a standard web browser (Google Chrome 64 bit), a new patient was created, and a "jpeg"-formatted cephalometric X-ray image was uploaded. The files were in grayscale format, and the image properties of the film were 2.232×2.304 pixels, 150 dpi, and 8 bits. Once the images were uploaded, the AlgoCeph system automatically identified all the anatomical points. The screen used for the analysis was 21.5" in size. Calibration was set to 20 mm, and the analysis was downloaded to the computer without any correction (Figure 2). The same set of data, after the automatic tracing, was also manually corrected for landmark position and downloaded to the computer.

Statistical Analysis

Statistical analysis was conducted using the Statistical Package for Social Sciences version 23.0 software (IBM Corp.; Armonk, NY, USA). The mean, minimum, maximum, and SD of all the measurements were calculated for each tracing system. Inter-group comparisons were made with one-way analysis of variance (ANOVA), and the Tukey test was used for post hoc testing. Intra-class and inter-class (manual tracings) variations were studied using intra-class correlation coefficients (ICC) with a confidence interval of 95%.

RESULTS

The ICC values calculated for repeated measurements to detect the method of error with each tracing technique are reported in Table 2. For manual measurements, the "ground truth" values were used, that is, the mean remeasurements of the 3 operators. All the ICCs exceeded 0.85, except for the dental landmarks: I-NA (°), I-NB (°), and I-NB (mm) traced with CephX. These landmarks showed a higher ICC when manual correction was performed. Most of the other values were above 0.9, regardless of the tracing method used, thereby providing an indication of very high intra-rater reliability.

Table 4. Comparison of skeletal, dental and soft tissue measurements by 4 different cephalometric analysis methods

Measurements	CephX (cx)			CephX corrected (cxc)			CephNinja (cn)			Dolphin (d)			Manual (m) "ground truth"			
	Min	Max	Mean ±SD	Min	Max	Mean ±SD	Min	Max	Mean ±SD	Min	Max	Mean ±SD	Min	Max	Mean ±SD	p-value
SKELETAL																
SNA (°)	73.6	87.2	79.9 ± 3.2	73.8	87.2	80 ± 3.2	73.7	86.7	79.6 ± 3	72.4	89.7	79.6 ± 3.4	75	86	79.8±2.8	NS
SNB (°)	69.6	84.4	76.6 ± 3.2	70	84.4	76.7 ± 3.6	69.6	84.6	76.3 ± 3.6	69.1	87.7	76.5±4.4	70.5	84.5	76.6±3.4	NS
ANB (°)	-2.2	8.2	3.2 ± 2.5	-2.3	8	3.3 ± 2.6	-1.1	7.9	3.3 ± 2.5	-1.4	8.1	3.3 ± 2.6	-1	7,6	3.2±2.3	NS
GoGn-SN (°)/ GoMe-SN (°)	28.3	55.4	40.3 ± 6.5	25.1	54.4	38.7 ± 6.6	20	53.6	34.7 ± 7	24.3	54.4	35.7 ± 7.1	20.8	51	33.8±6.9	cx-cn**, cx-d*, cx-m**
DENTAL																
I-NA (°)	17.6	38.5	27.2 ± 4.5	16.3	38.4	27.6 ± 5.5	11.2	34.8	24.3 ± 5.5	14.2	35	24 ± 5.9	15	36.3	25.3±5.4	cx-d * cxc-m *
I-NA (mm)	1	9.4	4.8 ± 1.8	1.7	9.2	5.1 ± 1.8	2.7	8.5	6 ± 1.4	1.1	8.4	4.9 ± 1.9	3	9.33	6.3±1.6	cx-cn*, cx-m** cn-d*, d-m**, cxc-m **
I-NB (°)	10	33.5	22.5 ± 5.9	9.8	36.4	24.7 ± 6.4	11.3	43.2	27 ± 6.6	9.3	43.1	26.7 ± 7.5	12.3	40	26.8±6.5	cx-cn*, cx-d*, cx-m*
I-NB (mm)	-0.7	9.4	4.9 ± 2.5	-0.8	9	4.8 ± 2.4	1.2	9.2	5.7 ± 1.9	-0.5	10.2	5.3 ± 2.5	0.8	9.5	5.8±1.9	cxc-m *
I-I (°)	112.7	144.9	126.9 ± 8.2	107.9	152	124.2±9.4	103.7	152.4	125.3 ± 10	101.2	155.2	125.8 ± 11.2	106.6	149.6	124.3±9.2	NS
OCC-SN (°)	9	24.7	16.4 ± 4.3	9.9	25.3	16.6±4.3	9.9	30.1	17.6 ± 4.1	6	27.7	17.7 ± 4.7	8.3	26.3	17.1±4.1	NS
SOFT TISSUE																
UL E-line (mm)	-10.6	1.2	-4.5 ± 3.4	-9.9	0.9	-4.2±3.1	-9.3	1.9	-4.1 ± 2.9	-9.6	1.5	-4.4 ± 3	-9.33	1.33	-4.24±2.9	NS
LL E-line (mm)	-6.7	3.1	-1.2 ± 3	-7.2	3.7	-1.1±3	-7.5	4.1	-1.1 ± 2.7	-7.7	4.4	-1.2 ± 2.9	-8.1	3.8	-1.4±2.8	NS

NS: Non-significant; CX: CephX; CN: CephNinja; D: Dolphin; M: Manual; Min: Minimum; Max: Maximum; SD: Standard deviation
*p<0.05, **p<0.01, ***p<0.001
GoGn-SN (°) / GoMe-SN (°): CephX uses the GoMe plane instead of GoGn
For the manual measurements, the "ground truth" values were used: the mean measurements of 3 examiners

Table 5. Comparison of the analysis time between the 4 different cephalometric analysis methods

	CephX (cx)			CephX corrected (cxc)			CephNinja (cn)			Dolphin (d)			Manual (m) "ground truth"			
	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	p
Duration (sec)	20	46	29.5 ± 5.4	35	81	58.7 ± 11.8	60	155	100.1 ±17.4	105	172	129.4±19.9	418	841	551±105	cx-cn***, cx-d***, cx-m***, cn-m***, d-m***, cxc-cx**, cxc-cn ***, cxc-d ***, cxc-m ***

**p<0.01, ***p<0.001, For the manual analysis, the mean time of measurements made by three examiners are given.
Min: Minimum; Max: Maximum; SD: Standard deviation

The ICC values for the inter-examiner correlation for manual measurements are shown in Table 3. All the values were above 0.9, indicating very high inter-examiner reliability between the 3 operators.

For the inter-group comparisons of the cephalometric values and the tracing times, the results of the one-way ANOVA and Tukey test are shown in Table 4 and Table 5, respectively.

Regarding the skeletal parameters, no statistically significant differences for SNA, SNB, and ANB were detected among the 4 tracing systems. The mean values for the GoGn-SN measurements were significantly higher in the CephX group than in the other 3 groups ($p<0.05$), but when manual correction was performed, the GoGn-SN value became similar to the values obtained by the other tracing methods (Table 4).

Regarding the dental parameters, there were no statistically significant differences among the 4 tracing systems for I-I and Occ-SN measurements. Significantly higher means of I-NA (°) were observed using CephX compared with Dolphin ($p<0.05$) and CephX corrected compared with manual tracing, whereas the mean I-NB (°) was significantly lower in CephX than in CephNinja, Dolphin, and manual tracing ($p<0.05$). The mean I-NA (mm) and I-NB (mm) were significantly lower in CephX than in manual tracing ($p<0.05$) regardless of manual correction, whereas higher values were obtained in CephNinja than in CephX and Dolphin ($p<0.05$).

The soft tissue measurements were similar in all 4 tracing systems ($p>0.05$).

The shortest analyzing time was obtained using CephX, followed by CephX corrected, CephNinja and Dolphin, whereas manual tracing took the longest time (Table 5).

DISCUSSION

Digital systems are increasingly used in cephalometry because of rapid advances in computer technology. Cephalometric analysis is not only available as computer software but also as applications on smartphones or online, where automatic tracing is possible. Regardless of the method used, the most important criteria for tracing are accuracy and a high rate of reproducibility. Therefore, the focus of this study was to compare the accuracy of manually traced lateral cephalograms with automatic, digitized, or app-aided tracings. The principal finding of this study was that automatic tracing with CephX is significantly faster than the other methods, but the software needs improvement to become more reliable in the majority of dental measurements and also for GoGn-SN (°). After manual correction of the landmarks on CephX, measurements similar to digitized and app-aided tracings can be obtained in a significantly shorter time.

The threshold for clinically relevant differences of cephalometric measurements varies in the literature; however, a difference that is statistically significant but is smaller than 2 units of measurement (millimeters or degrees) is considered to be within the clinically acceptable limits (12, 13). Therefore, all statistically significant differences for dental and skeletal measurements found in this study using CephX were also clinically significant. Thus, the null hypothesis that all the 4 methods were no different can be rejected regarding the skeletal measurement of GoGn-SN (°) and the dental measurments, including I-NA (°), I-NA (mm), I-NB (°), and I-NB (mm). The null hypothesis can be accepted for SNA (°), SNB (°), ANB (°), I-I (°), OCC-SN (°), UL E-line (mm), and LL E-line (mm).

Previous researches have shown that the inter-operator error is greater than the intra-operator error and that the experience of the observer when locating the landmarks also affects the random error (13-15). To avoid such error, the digital measurements in this study were carried out by a single experienced examiner. However, since fully automatic tracing systems are deterministic i.e., the same image will give the same result every time, unlike manual tracings, which are known for having high inter-observer error, the CephX measurements in this study were compared with a "manual ground truth" that was obtained with 3 manual observers instead of a single observer. The inter-examiner reproducibility for the manual tracings was very high, and the majority of the ICC values for the repeated measurements were also high, irrespective of the tracing method, indicating that a high intra-operator reliability (Tables 2 and 3).

The use of cephalometric software may diminish the errors that occur during manual tracings obtained by drawing and measuring with a ruler and a protractor (16, 17). However, some measurements, particularly those involving the maxillary and mandibular incisors, are difficult to identify; hence, such structures have been shown to have low reliability not only in manual but also in digital tracings, despite the possibility of using filtering and zooming (14, 18). These results are in accordance with our study, i.e., the measurements related to the landmarks including incisors revealed significant differences, and the most unreliable system was the CephX, which was also reflected by the lower ICC values. This error may be due to where the incisal landmark is placed. CephNinja and manual tracing use the most prominent facial point of the incisor, whereas CephX uses the incisal point of the tooth. Additionally, automatic identification of landmarks is always associated with an error that will increase if a line consisting of 2 points is measured because this will be affected by the errors of the 2 points rather than a single one (19). However, when CephX landmarks were manually corrected, dental linear and angular measurements on incisors were similar to app-aided and computerized tracings (Table 4). In general, angular measurements were more reliable than linear ones, especially when CephNinja, Dolphin, and manual tracing were used. These results are in accordance with the findings obtained by other investigators (20, 21).

Previous studies have reported that nasion and gonion are inconsistent points and sources of mistakes, which is in line with the findings of our study, as measurements related to these points revealed significant differences using CephX. Another source of error that may explain the higher GoGn-SN (°) measurements obtained by CephX and compared to the other methods, is that the program uses the GoMe plane instead of the GoGn plane when the GoGn-SN value is measured (12, 22). This shortcoming can be adjusted by manually correcting the landmark.

Correction of automatically traced points on CephX has been performed by other investigators, resulting in clinically insignificant FMA angle (Frankfurt plane/Mandibular plane angle) obtained by the CephX group compared with computerized tracing group (23).

The resolution of the images is an important criterion for the validity of the results. Digital images of 150 dpi, 8 bits, have been reported to be sufficient for clinical purposes (7). In this study, a resolution of 150 dpi was used for all the 4 tracing methods to allow for comparison and also because it is recommended by the software manufacturers as it facilitates identification of the landmarks. The specific anatomical landmarks used in this study were chosen partly because the app-based application did not offer more parameters and partly because of the commonalities among the 4 methods. Moreover, these landmarks were chosen also because they are commonly used for orthodontic diagnosis and treatment planning.

The time required to identify and trace the anatomical structures differs significantly between experienced and inexperienced operators when digital tracings are used but cannot be reduced with manual tracing (21). In this study, the time required to make the digital measurements was substantially shorter than for the manual method, which is in line with the findings by other investigators (7, 11). Analyzing time with CephX was found to be 13 times faster than manual tracing and about 3 times faster than with CephNinja and Dolphin (Table 5). Also, when manual correction of CephX landmarks was made, the analyzing time was significantly shorter compared with the other methods. The time required to make a cephalometric analysis should not include the time required to make a diagnosis or a treatment plan. Even if the shortest tracing time was obtained with CephX, it was also the method that was less reliable in the majority of the dental measurements. The reliability and the validity of the tracing method should, therefore, always be superior to the tracing time; however, it should be pointed out that the manual correction of CephX landmarks results in similar measurements to CephNinja and Dolphin and seems to be a promising method for use in the clinical practice.

CONCLUSION

With the development of fully automated methods, cephalometric analyses can be performed faster and more reliably in the near future. On the basis of the results from this study, it can be concluded that CephX requires improvement to provide similar results as the other methods that were assessed. However, manual correction of CephX landmarks gives equivalent results to digital tracings using CephNinja and Dolphin with significantly shorter analyzing time.

Ethics Committee Approval: This study was approved by the Research Ethics Committee of Trakya University, Faculty of Medicine (Approval No: TÜTF-BAEK 2017/318).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – P.M., J.N.; Design – P.M., J.N.; Resources – P.M.; Materials – P.M.; Data Collection and/or Processing – P.M.; Analysis and/or Interpretation – P.M., J.N.; Literature Search – P.M., J.N.; Writing Manuscript – P.M., J.N.; Critical Review – P.M., J.N.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: This study was supported by Trakya University Scientific Research Projects (Project No: 2018/39).

Acknowledgements: We would like to thank Melis Seki and Sevgi Ersay who helped in tracing the manual cephalometric films.

REFERENCES

1. Broadbent BH. A new x-ray technique and its application to orthodontia. Angle Orthod 1931; 1: 45-66.
2. Naoumova J, Lindman R. A comparison of manual traced images and corresponding scanned radiographs digitally traced. Eur J Orthod 2009; 31: 247-53. [Crossref]
3. Phatak SM, Daokar SS. Orthodontic apps: A stairway to the future. Int J Orthod Rehabil 2019; 10: 75-81. [Crossref]
4. Prgomet M, Georgiou A, Westbrook JI. The impact of mobile handheld technology on hospital physicians' work practices and patient care: A systematic review. J Am Med Inform Assoc 2009; 16: 792-801. [Crossref]
5. Livas C, Delli K, Spijkervet FKL, Vissink A, Dijkstra PU. Concurrent validity and reliability of cephalometric analysis using smartphone apps and computer software. Angle Orthod 2019; 89: 889-96. [Crossref]
6. Forsyth DB, Shaw WC, Richmond S, Robert CT. Digital imaging of cephalometric radiographs. Part 2: image quality. Angle Orthod 1996; 66: 43-60.
7. Sayinsu K, Isik F, Trakyali G, Arun Tülin. An evaluation of the errors in cephalometric measurements on scanned cephalometric images and conventional tracings. Eur J Orthod 2007; 29: 105-8. [Crossref]
8. Celik E, Polat-Ozsoy O, Toygar-Memikoglu TU. Comparison of cephalometric measurements with digital versus conventional cephalometric analysis. Eur J Orthod 2009; 31: 241-6. [Crossref]
9. Mosleh MAA, Baba MS, Malek S, Almaktari RA. Ceph-X: Development and evaluation of 2D cephalometric system. BMC Bioinformatics 2016; 17: 499. [Crossref]
10. Shettigar P, Shetty S, Naik RD, Basavaraddi SM, Patil AK. A Comparative evaluation of reliability of an android-based app and computerized cephalometric tracing program for orthodontic cephalometric analysis. Biomed Pharmacol J 2019; 12: 341-6. [Crossref]
11. Uysal T, Baysal A, Yagci A. Evaluation of speed, repeatability, and reproducibility of digital radiography with manual versus computer-assisted cephalometric analyses. Eur J Orthod 2009; 31: 523-8. [Crossref]
12. Chen YJ, Chen SK, Yao JC, Chang HF. The effects of differences in landmark identification on the cephalometric measurements in traditional versus digitized cephalometry. Angle Orthod 2004; 74: 155-61.
13. Schulze RKW, Gloede MB, Doll GM. Landmark identification on direct digital versus film based cephalometric radiographs: A human skull study. Am J Orthod Dentofacial Orthop 2002; 122: 635-42. [Crossref]

14. Paixão MB, Sobra MC, Vogel CJ, de Araujo TM. Comparative study between manual and digital cephalometric tracing using Dolphin Imaging software with lateral radiographs. Dent Press J Orthod 2010; 15: 123-30. [Crossref]
15. Lagravere MO, Low C, Flores-Mir C, Chung R, Carey JP, Heo G, et al. Intraexaminer and interexaminer reliabilities of landmark identification on digitized lateral cephalograms and formatted 3-dimensional cone-beam computerized tomography images. Am J Orthod Dentofacial Orthop 2010; 137: 598-604. [Crossref]
16. Baumrind S, Frantz RC. The reliability of head film measurements: 1. Landmark identification. Am J Orthod 1971; 60: 111-27. [Crossref]
17. Trpkova B, Major P, Prasad N, Nebbe B. Cephalometric landmarks identification and reproducibility: A meta analysis. Am J Orthod Dentofacial Orthop 1997; 112: 165-70. [Crossref]
18. Chan CK, Tng TH, Hägg U, Cooke MS. Effects of cephalometric landmark validity on incisor angulation. Am J Orthod Dentofacial Orthop 1994; 106: 487-95. [Crossref]
19. Chen YJ, Chen SK, Chang HF, Chen KC. Comparison of landmark identification in traditional versus computer-aided digital cephalometry. Angle Orthod 2000; 70: 387-92.
20. Leonardi R, Giordano D, Maiorana F, Spampinato C. Automatic cephalometric analysis. Angle Orthod 2008; 78: 145-51. [Crossref]
21. Geelen W, Wenzel A, Gotfredsen E, Kruger M, Hansson LG. Reproducibility of cephalometric landmarks on conventional film, hardcopy, and monitor-displayed images obtained by the storage phosphor technique. Eur J Orthod. 1998; 20: 331-40. [Crossref]
22. Aksakallı S, Yılancı H, Görükmez E, Ramoğlu Sİ. Reliability assessment of orthodontic apps for cephalometrics. Turk J Orthod 2016; 29: 98-102. [Crossref]
23. Alqahtani H. Evaluation of an online website-based platform for cephalometric analysis. J Stomatol Oral Maxillofac Surg 2020; 121: 53-7. [Crossref]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.19109

Original Article

Evaluation of Stress Pattern Caused by Mini-Implant in Mandibular Alveolar Bone with Different Angulations and Retraction Forces: A Three-Dimensional Finite Element Study

Manreet Sidhu[1], Vinay Kumar Chugh[2], Kuldeep Dmello[3], Anurag Mehta[4], Ankita Chugh[5], Pradeep Tandon[6]

[1]Private Practice, New Delhi, India
[2]Department of Dentistry, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India
[3]Department of Orthodontics, KD Dental College, Mathura, Uttar Pradesh, India
[4]Department of Orthodontics, Vyas Dental College & Hospital, Jodhpur, Rajasthan, India
[5]Department of Dentistry, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India
[6]Department of Orthodontics, King George Medical University Lucknow, Uttar Pradesh, India

Cite this article as: Sidhu M, Chugh VK, Dmello K, Mehta A, Chugh A, Tandon P. Evaluation of Stress Pattern Caused by Mini-Implant in Mandibular Alveolar Bone with Different Angulations and Retraction Forces: A Three-Dimensional Finite Element Study. Turk J Orthod 2020; 33(3): 150-6.

ABSTRACT

Objective: The objective of the study was to evaluate the stress pattern in cortical and cancellous bones, periodontal ligament, and in the implant itself when a mini-implant (MI) is inserted in the inter-radicular space between mandibular first molar and second premolar at various angulations and different retraction forces.

Methods: Finite element study was conducted with MI insertion at 30°, 45°, 60°, 75°, and 90° angulations in the mandibular posterior region (between second premolar and first molar). At these angulations, horizontal forces of 150, 200, and 250 g were applied to the middle of the MI head. von Mises stress values were then evaluated using the ANSYS software.

Results: Highest von Mises stress values were detected in the MI itself, followed by cortical bone, cancellous bone, and periodontal ligament. The von Mises stress values in cortical bone were highest at 30° angulation and lowest at 90° angulation. In the cancellous bone, the stress value was found to be maximum at 90°. The von Mises stress values in the MI were lowest at 90°. In all four structures, as the load increased from 150 to 250 g, the von Mises stress values increased.

Conclusion: The von Mises stress values in the cortical bone, MI, and periodontal ligament were found to be lowest at 90°. Placement of the MI at 90° appears to be an ideal angulation when applied with a horizontal load. Force range used is within clinically recommended levels; however, the increase in load causes an increase in the stress values.

Keywords: Cancellous bone, cortical bone, finite element model, periodontal ligament, mini-implant

Main points:

- In this finite element model, von Mises stress values were found to be least at 90° in all structures except cancellous bone.
- Perpendicular placement of mini-implant appears to be the ideal insertion angulation.
- Increase in load values causes an increase in the stress values at all angulations.

INTRODUCTION

The advent of skeletal anchorage in orthodontics is slowly replacing the traditional methods of reinforcing orthodontic anchorage. Mini-implants (MIs) are especially advantageous owing to their miniature size, easy placement and removal techniques, moderately low cost, and most importantly, leeway of early loading (1, 2). Nevertheless, there are certain risks associated with MIs that involve chances of screw fracture, especially during placement; damage to vital structures such as roots, nerves and blood vessel; and peri-implantitis (3-5). Contrary to a dental implant, MI is a temporary anchorage device; hence, its primary stability is pertinent to treatment suc-

Address for Correspondence: Vinay Kumar Chugh, Department of Dentistry, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India
E-mail: drvinaychd@yahoo.com

Received: December 20, 2019
Accepted: July 20, 2020
Available Online Date: July 18, 2020

cess as there is a possibility of transmitting orthodontic forces to the alveolar bone (6).

The MI success rate was reported to be as high as 89.9 % in a study by Wu et al. (7). The results of their study suggested that implant diameters greater than 1.4 mm in maxilla and less than 1.4 mm in mandible were critical for MI success. Other elements vital to MI success rate are availability of superior bone quality at the implant site with adequate width of attached gingiva and a delayed loading of four weeks after MI insertion (8). Adequate measures to control factors attributing to local inflammation would further enhance MI stability.

Nonetheless, the failure rates of MI have been still reported as high as 30% (5, 9-11). Biological and mechanical factors associated with MI failure include site of implantation, orthodontic force level, inflammation, non-keratinized implant sites, screw diameter, and cortical bone thickness (4, 10, 12, 13). Other factors that are less commonly associated with MI failure are insertion angle, exposure length/implanted depth, direction of force, bone quality, and loading conditions (9, 14-16). Numerous suggestions have been provided to increase the MI stability, but they usually lack the support of mechanical reasoning (14). The process by which force transmission occurs from external of MI to the internal bone surface is one of the keys to the clinical success of MI (17). Hence, there was a need to study the effects of individual variables on each other and the MI.

Finite element analysis (FEA) or finite element model (FEM) is a computer-based numerical simulation method that has extensive application in mathematical physics and has been widely used in estimating the mechanical behavior of engineering structures. In orthodontics, its application involves the evaluation of various biomechanical force systems with various appliances (18). The purpose of this finite element study was to estimate the von Mises stress in various structures (bone, periodontal ligament, and MI) when an MI is placed at different angulations and subjected to varying loads. This will help to determine an ideal angulation of an MI that can be loaded safely with an optimal orthodontic force to achieve adequate primary stability, and thus reduce the failure of MI in orthodontics.

METHODS

A FEM was created using a dedicated software (ANSYS Workbench 14.5, Canonsburg, PA, USA). The FEM was composed of five elements: 1- the mandibular second premolar and first permanent molar having 0.2 mm thickness of periodontal ligament and cancellous bone and 2 mm thickness of cortical bone (Figure 1); 2- MI model (diameter, length, and screw); 3- modeling of cortical and cancellous bones and thickness of periodontal ligament; 4- FEM of MI when placed into bone at various angulation (Figure 2); and 5- Young's modulus and Poisson's ratio for all constituent structures under experiment. The study was approved by the Institutional Ethics Committee, All India Institute of Medical Sciences, Jodhpur (AIIMS/IEC/ 2018/697).

The geometry of the FEM of the lower first molar and second premolar was determined using standard measurement (19). The periodontal ligament was replicated to a thickness of 0.2 mm around the root along with 0.15 mm thin cementum layer (20). Orthodontic MI made of pure titanium (diameter, 1.6 mm; length, 8 mm; thread ridge height, 0.2 mm; thread pitch, 0.6 mm)

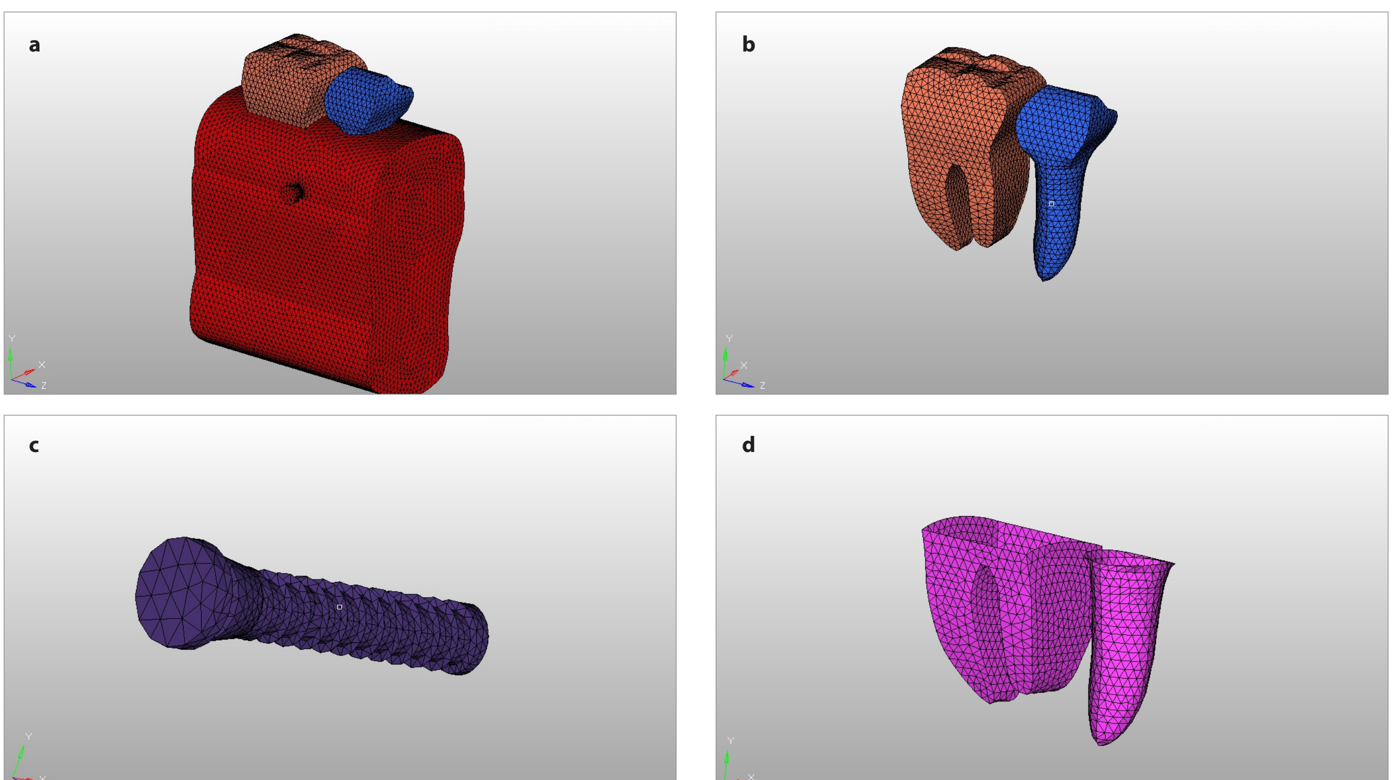

Figure 1. a-d. (a) FEM consisting of (b) tooth, (c) MI, (d) periodontal ligament and bone elements. FEM: finite element model

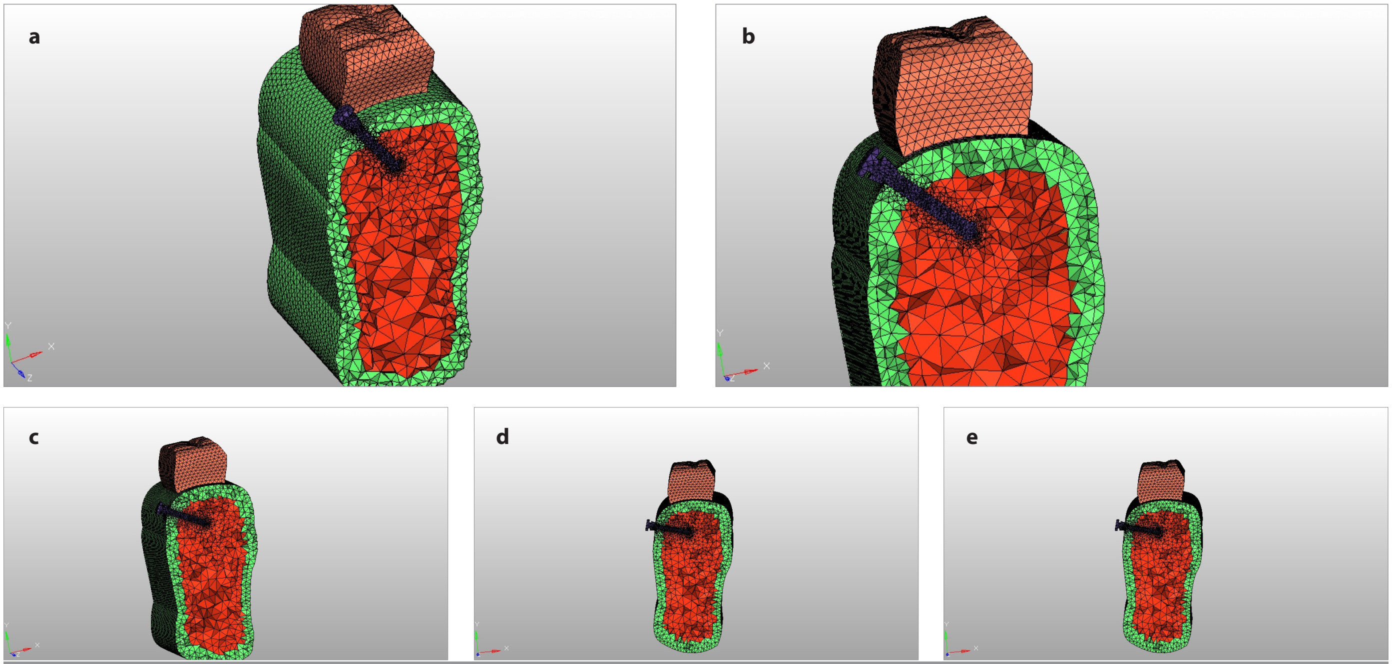

Figure 2. a-e. FEM consisting of MI at different angulations: (a) 30°, (b) 45°, (c) 60°, (d) 75° , and (e) 90°. FEM: finite element model

MI: Mini-implant

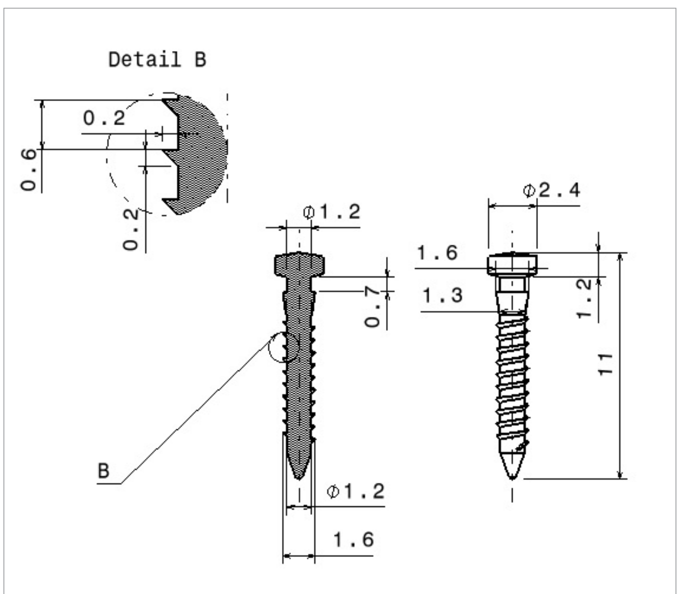

Figure 3. Schematic representation of implant design used in this finite element study

was modeled. The MI dimensions (Figure 3) were created on the basis of the research by Motoyashi et al. (21). Based on the classical theory of elasticity and for the ease of modeling, it was assumed that the constituent material was isotropic and homogeneous. The behavior of the constituent material was quantified by Poisson's ratio and Young's modulus as per the previous research (22). The material properties for MI, bone, and periodontal ligament are given in Table 1.

The site of placement of MI was assumed to be in between mandibular second premolar and first molar on the basis of a morphometric study (23). FEM was created with MI insertion at 30°, 45°, 60°, 75°, and 90° angulations, and at each angulation a horizontal load of 150, 200, and 250 g was applied (24). The boundary between the MI and the bone elements was secured to demarcate from other interfaces. Gap elements that existed between the MI and periodontal membrane were considered to be negligible. On the application of different loads at each angulation, stress values were calculated in all component structures and at the neck of the MI. Table 2 represents the number of nodes and elements created in the study.

Table 1. Material properties of constituent materials

Materials	Young's modulus (MPa)	Poisson's ratio
Titanium	110,000	0.35
Cortical bone	14,000	0.30
Cancellous bone	1,370	0.30
Periodontal membrane	69	0.45
Tooth	18,600	0.31

MPa: Megapascal

Table 2. Number of nodes and elements generated for each model

Model	Elements	Nodes
Model30	140,039	27,564
Model45	140,053	27,531
Model60	140,247	27,594
Model75	140,416	27,614
Model90	175,121	33,319

RESULTS

The von Mises stress distribution in the cortical bone, cancellous bone, periodontal ligament, and MI itself was assessed using a colored scale (Figure 4). Low and high stress values in the scale are depicted by blue and red color, respectively. Table 3 represents numerical values of von Mises stress in the cortical and cancellous bones, periodontal ligament, and MI at 30°, 45°, 60°, 75°, and 90° insertion angulations at varying loads. The von Mises stress values in the cortical bone were highest (4.71, 6.28, and 7.85 megapascal [MPa] at 150, 200, and 250 g, respectively) at 30° angulation (Figure 5). The values for other angulations were lower. The von Mises stress values in cancellous bone were highest (0.020, 0.026, and 0.033 MPa at 150, 200, and 250 g, respectively) at 90° angulation. The values were lowest for 60-degree angulation. Whereas the von Mises stress values in periodontal ligament were lowest (0.0001, 0.0001, and 0.0002 MPa at 150, 200, and 250 g, respectively) at 90° angulation, the values were low and comparable at 60- (0.0003, 0.0004, 0.0005 MPa at 150, 200, and 250 g, respectively) and 75- (0.0002, 0.0002, 0.0003 MPa at 150, 200, and 250 g, respectively) degree angulations and highest at 30° angulation.

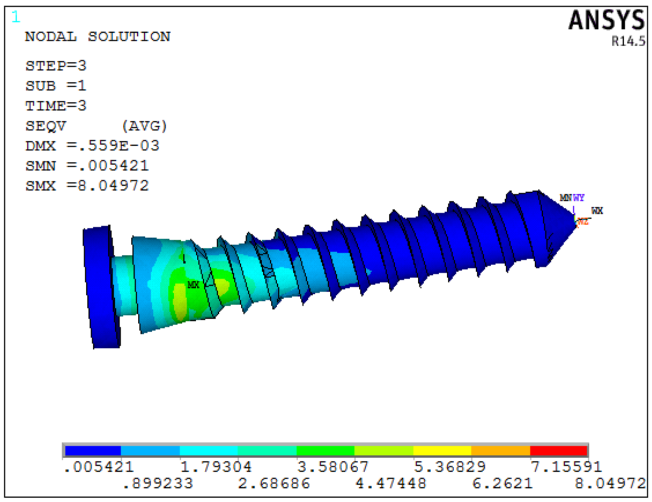

Figure 4. von Mises stress at various MI sites depicted by a different scheme of colors. MI: Mini-implant

The von Mises stress values in the MI were lowest (4.83, 6.44, and 8.04 MPa at 150, 200, and 250 g, respectively) at 90° angulation followed by 45° angulation, and the values were higher at 30°, 60°, and 75° insertion angulations. Stress values were found to be the highest within MI when compared with cortical bone, cancellous bone, and periodontal ligament. The least amount of stress was observed in the periodontal ligament at all angulations. Overall, the von Mises stresses in cortical bone, cancellous bone, periodontal ligament, and MI increased with an increase in the amount of the horizontal load at all angulations.

DISCUSSION

The FEM simulated the biomechanical force system that is applied clinically and allowed to evaluate the response of dentoalveolar system. Posterior region of the mandibular bone was chosen as a site of implant placement because previous studies have reported a lower success rate in mandible as compared with maxillary bone (5, 25). This is in contrast to dental implants where the opposite is true (3-5). Cortical bone thickness of 2

Table 3. Maximum von Mises stress values induced at various insertion angulations and different horizontal loads

		Horizontal load		
		150 g	200 g	250 g
Model	MI Insertion angulations	von Mises stress (MPa)		
Cortical bone	30	4.71144	6.28129	7.85241
	45	2.49361	3.32481	4.15601
	60	2.27166	3.02887	3.78609
	75	2.50206	3.33608	4.1701
	90	2.1329	2.84387	3.5548
Cancellous bone	30	0.0065	0.0087	0.0109
	45	0.0066	0.0088	0.0110
	60	0.0053	0.0071	0.0089
	75	0.0070	0.0093	0.0116
	90	0.0196	0.0261	0.0327
Periodontal ligament	30	0.000612	0.000817	0.001021
	45	0.000396	0.000528	0.000660
	60	0.000286	0.000382	0.000477
	75	0.000153	0.000204	0.000255
	90	0.0000982	0.000131	0.000164
MI	30	9.04785	12.0638	15.0798
	45	6.0885	8.118	10.1475
	60	9.48337	12.643	15.8037
	75	9.83599	13.1147	16.3933
	90	4.8298	6.4397	8.0497

MI: Mini-implant; MPa: Megapascal

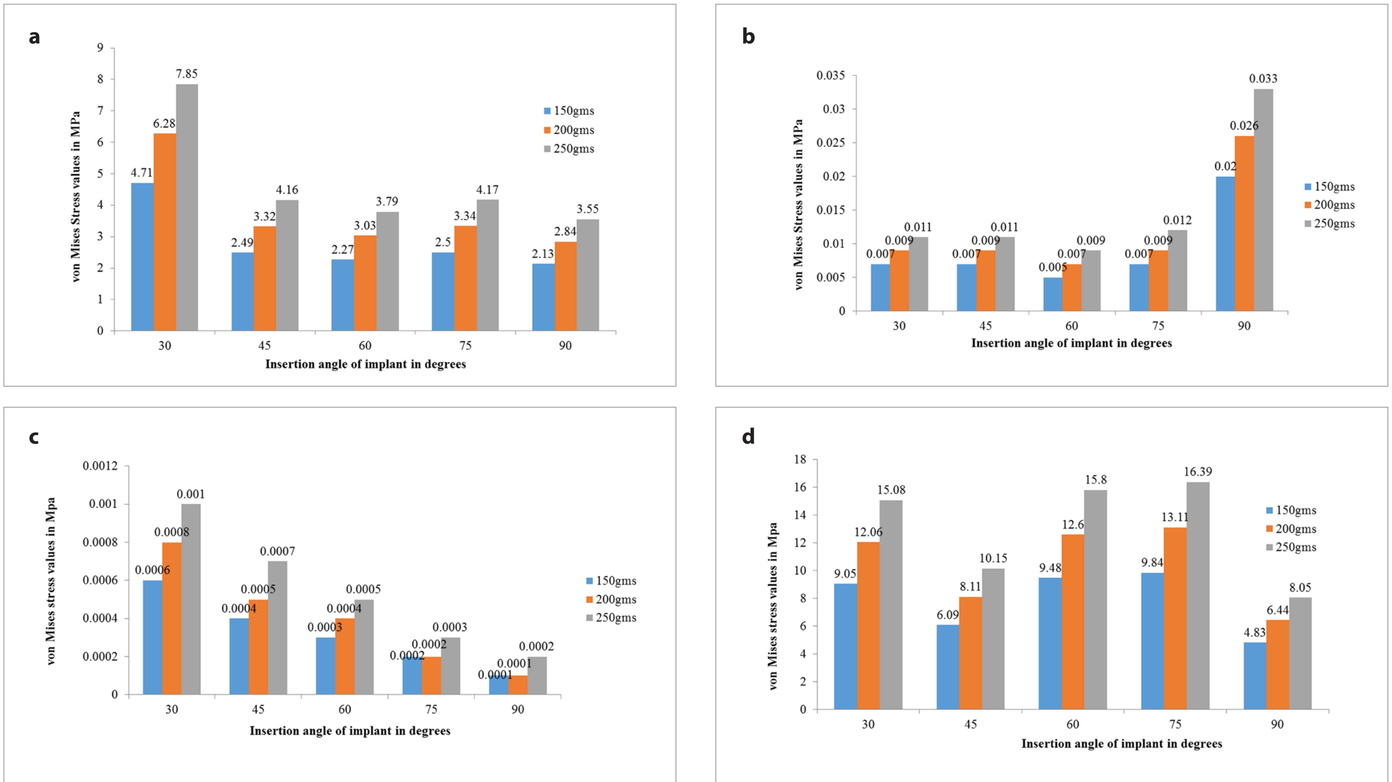

Figure 5. a-d. von Mises stress values induced at various insertion angulation in (a) cortical bone, (b) cancellous bone, (c) periodontal ligament, and (d) MI

MI: Mini-implant

mm between second premolar and first permanent molar was modeled as this is the most common site of MI placement. Screw diameter greater than 1.8 mm usually requires larger inter-radicular space, whereas screw diameter less than 1.5 mm reduces the primary stability. Therefore, a screw diameter of 1.6 mm was chosen, which would provide sufficient mechanical properties without requiring a wide insertion space (26-28). It has been widely reported that the majority of the MIs have the ability to stand 100-200 g of horizontal load (early or immediate) with ease and the magnitude is sufficient for various tooth movements (29-32). The orthodontic force levels selected in this study were 150, 200, and 250 g, to simulate clinically viable conditions.

This study showed that von Mises stress values increased with increasing horizontal loading force. The forces considered in this study were within the optimum ranges for clinical conditions, such as individual canine retraction using horizontal component of force of 150 g or en masse retraction using horizontal component of force in the range of 200-250 g. Lin et al. (9) conducted a study and reported that the orthodontic force direction had no statistically significant effect on stress values in cortical bone. Hence, different directions of loading force were not taken into consideration in this study. Critical stress curves as drawn in the study by Li et al. (33) for overload and underload resorption demonstrated that cortical bone resorption because of overloading was seen in areas with von Mises stress greater than 25-28 MPa. The authors suggested that injury to the periodontal membrane during MI insertion may cause overload bone resorption especially when the integrity of the root is maintained. This overloading could be attributed to MI failure (33). The findings of Robert et al. (30) also suggest that forces between 1 and 3 N do not affect implant stability. Zhang et al. (16) theorize that within the implant-cortical bone spongy bone system, higher stresses are received by cortical bone primarily because of its high modulus of elasticity. Similar findings were also noticed in this study as the stress in the cortical bone was higher in comparison with cancellous bone.

Regarding the effect of angulations on von Mises Stress, the increase in MI insertion angulation appears to be inversely proportional to stress values produced in the cortical bone. The highest stress values were observed in the cortical bone when the MI insertion angulation was at 30°. The stress values in the cortical bone were minimum at 90° angulation and values at 60°, 75°, and 45° were in between. Previous studies have shown that cortex thickness primarily governs the transmission of force from mini-screw to bone, and cancellous bone thickness plays a minor role (34, 35). More importantly, cortical bone is more resistant to distortion and can withstand higher loads mainly because of its higher modulus of elasticity. Dense cortical bone is advantageous from the primary stability perspective; however, if the site lacks sufficient preparation, secondary stability can be significantly compromised because of increased compression of bone (36). Primary stability is imperative in early healing and remodeling phase, especially when there is early loading of the implant.

The stress values in cancellous bone were of the lower magnitude when compared with cortical bone. The minimum stress values were detected in cancellous bone when the implant was at 60° angulation. The stress was maximum at 90° angulation. The long-term success of the implant after the healing phase and during the loading phase is primarily dependent on secondary stability. No attempt was made to simulate secondary stability in this study to avoid complex configuration. Reduced stress in cancellous bone can be a factor that enhances secondary stability, but this needs further research. The von Mises stress in the periodontal ligament was much lower than both bony elements.

The von Mises stress in the MI was mostly present at the neck of the implant close to bone-implant interface. The minimum stress value was found in the bone when the implant was at 90° angulation. Considering that MIs are made of pure titanium having superior properties, the stress values at all angulations were low enough to presume that there may not be implant breakage up to 250 g of horizontal force. Excessive stress concentrations were detected in the MI at the cervical margin around first few threads. Similar findings have been presented by Meijer et al. (37), Barbier et al. (38), and Clelland et al. (39). However, Vasquez et al. (40) used a dental implant for anchorage in their study and contested this point that even though the stress concentration was localized in the cervical margin and first threads, these stresses are of very low magnitude and inadequate to cause the failure of the implant. Consequently, the osseo-integrated dental implant may act as potential anchor units as they are better suited to withstand orthodontic forces. The results of this study are in agreement with the research by Jasmine et al. (41) who found that at a horizontal load of 200 g, maximum stress values were within the MI, followed by cortical bone and least in the cancellous bone.

There has been a considerable debate whether the insertion angulation should be perpendicular or angulated. Jasmine et al. (41) reported that a decrease in stress values was observed in both MI and cortical bone as the insertion angulation increased from 30° to 90°. They concluded that ideal MI insertion angulation should be at 90° for enhanced stability. The FEA by Perillo et al. (24) also advocated that placing mini-screws at 90° angle would result in improved stability than at angulation lesser or greater than 90°. On the contrary, as the insertion angle affects the primary stability the least, oblique or a diagonal insertion of MI is advantageous over perpendicular insertion because of its added biomechanical advantages (15). This argument is supported by the study by Wilmes et al. (15) who suggested that oblique placement may lead to a slightly greater primary stability, especially in the areas with poor or reduced bone quality. To achieve higher insertion torque values, insertion angulation ranging from 60° to 70° have also been suggested (15). This insertion angulation may also prove to be beneficial whenever there is insufficient inter-radicular space for MI placement and further help in the aversion of root contact.

FEM was constructed on the basis of the assumption that cortical and trabecular bones were isotropic and homogeneous. Other structures such as osteons, Haversian canals, and interstitial lamellae were not modeled as this would have further complicated the analysis. With the current knowledge, it is difficult to exactly predict the changes that occur with the passage of time with the same loading conditions. This study is a predictive analysis and must be used as a reference to aid clinical judgment.

CONCLUSION

The following conclusions were drawn from this FEM study:

- In the cortical bone, MI, and periodontal ligament, the von Mises stress value was least at 90° insertion angulation.
- The von Mises stress values were found to be highest in cortical bone and periodontal ligament when the MI was angulated at 30°.
- The von Mises stress values in cancellous bone were found to be highest and lowest at 90 and 60°, respectively.
- When applied with a horizontal load, placing the MI at 90° seems to be the ideal angulation. The von Mises stress values at 60°, 75°, and 90° insertion angulations are higher.
- The increasing loads cause an increase in stress levels. Even though the horizontal load of 250 g has the maximum stress levels, it is under the levels that can cause overloaded bone resorption and in turn MI failure.

Ethics Committee Approval: This study was approved by Institutional Ethics Committee, All India Institute of Medical Sciences, Jodhpur (AIIMS/IEC/ 2018/697).

Informed Consent: Informed consent is not necessary due to the nature of this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception – K.D., V.K.C., P.T.; Design – V.K.C., K.D., P.T.; Supervision – K.D., V.K.C.; Resources – M.S., A.M.; Materials – M.S., A.M.; Data Collection and/or Processing – M.S., A.M.; Analysis and/or Interpretation – V.K.C., M.S., A.M., A.C.; Literature Search – M.S., A.M., V.K.C., A.C.; Writing Manuscript – V.K.C., M.S., A.M., A.C., A.C., P.T.; Critical Review – V.K.C., K.D., M.S., A.M., A.C., P.T.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Roberts WE, Helm FR, Marshall KJ, Gongloff RK. Rigid endosseous implants for orthodontic and orthopedic anchorage. Angle Orthod 1989; 59: 247-56. [Crossref]
2. Cope JB. Temporary anchorage devices in orthodontics: A paradigm shift. Semin Orthod 2005; 11: 3-9. [Crossref]
3. Kuroda S, Sugawara Y, Deguchi T, Kyung HM, Takano-Yamamoto T. Clinical use of miniscrew implants as orthodontic anchorage: Success rates and postoperative discomfort. Am J Orthod Dentofacial Orthop 2007; 131: 9-15. [Crossref]
4. Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. Am J Orthod Dentofacial Orthop 2006; 130: 18-25. [Crossref]
5. Cheng SJ, Tseng IY, Lee JJ, Kok SH. A prospective study of the risk factors associated with failure of mini-implants used for orthodontic anchorage. Int J Oral Maxillofac Implants 2004; 19: 100-6.

6. Jiang L, Kong L, Li T, Gu Z, Hou R, Duan Y. Optimal selections of orthodontic mini-implant diameter and length by biomechanical consideration: A three-dimensional finite element analysis. Adv Eng Software 2009; 40: 1124-30. [Crossref]
7. Wu T, Kuang S, Wu C. Factors associated with the stability of mini-implants for orthodontic anchorage: A study of 414 samples in Taiwan. J Oral Maxillofac Surg 2009; 67: 1595-9. [Crossref]
8. Lai TT, Chen M. Factors affecting the clinical success of orthodontic anchorage: Experience with 266 temporary anchorage devices. J Dent Sci 2014; 9: 49-55. [Crossref]
9. Lin TS, Tsai FD, Chen CY, Lin LW. Factorial analysis of variables affecting bone stress adjacent to the orthodontic anchorage mini-implant with finite element analysis. Am J Orthod Dentofacial Orthop 2013; 143: 182-9. [Crossref]
10. Buchter A, Wiechmann D, Gaertner C, Hendrik M, Vogeler M, Wiesmann HP et al. Load related bone modelling at the interface of orthodontic microimplants. Clin Oral Implants Res 2006; 17: 714-22. [Crossref]
11. Wiechmann D, Meyer U, Buchter A. Success rate of mini and micro-implants used for orthodontic anchorage: a prospective clinical study. Clin Oral Implants Res 2007; 18: 263-7. [Crossref]
12. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2003; 124: 373-8. [Crossref]
13. Motoyashi M, Yoshida T, Ono A, Shimizu N. Effect of cortical bone thickness and implant placement torque on stability of orthodontic mini-implants. Int J Oral Maxillofac Implants 2007; 22: 779-84.
14. Liu TC, Chang CH, Wong TY, Liu JK. Finite element analysis of miniscrew implants used for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2012; 141: 468-76. [Crossref]
15. Wilmes B, Su YY, Drescher D. Insertion angle impact on primary stability of orthodontic mini-implants. Angle Orthod 2008; 78: 1065-70. [Crossref]
16. Zhang Y, Zhang D, Feng CJ. A three-dimensional finite element analysis for the biomechanical characteristics of orthodontic anchorage micro-implant. Shanghai Kou Qiang Yi Xue 2005; 14: 281-3.
17. Shalak R. Biomechanical considerations in osseointegrated prosthesis. J Prosthet Dent 1983; 49: 843-8. [Crossref]
18. Middleton J, Jones M, Wilson A. The role of the periodontal ligament in bone modeling: the initial development of a time dependent finite element model. Am J Orthod Dentofacial Orthop 1996; 109: 155-62. [Crossref]
19. Nelson SJ, Ash MM. Wheeler's dental anatomy, physiology and occlusion. 9th ed. St. Louis: Saunders Elsevier; 2010. p.13.
20. Newman MG, Takei HH, Carranza FA. Carrranza's Clinical Periodontology. 9th ed. St. Louis: Saunders; 2002. p.54.
21. Motoyashi M, Ueno S, Okazaki, N, Shimizu N. Bone stress for a mini-implant close to the roots of adjacent teeth.- A 3D Finite element analysis. Int J Oral Maxillofac Surg 2009; 38: 363-8. [Crossref]
22. Motoyoshi M, Yano S, Tsuruoka T, Shimizu N. Biomechanical effect of abutment on stability of orthodontic mini-implant: A finite element analysis. Clin Oral Impl Res 2005; 16: 480-5. [Crossref]
23. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. Am J Orthod Dentofacial Orthop 2006; 129: 721.e7-12. [Crossref
24. Perillo L, Jamilian A, Shafieyoon A, Karimi H, Cozzani M. Finite element analysis of miniscrew placement in mandibular alveolar bone with varied angulations. Eur J Orthod 2015; 37: 56-9. [Crossref]
25. Kuroda S, Yamada K, Deguchi T, Hashimoto T, Kyung HM, Takano-Yamamoto T. Root proximity is a major factor for screw failure in orthodontic anchorage. Am J Orthod Dentofacial Orthop 2007; 131: S68-S73. [Crossref]
26. Lietz T. Mini-screws: Aspects of assessment and selection among different systems. Ludwig B, Baumgaertel S, Bowman SJ editors. Mini-implants in orthodontics: Innovative achorage concepts. London: Quintessence; 2008. p.11-72.
27. Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. Am J Orthod Dentofacial Orthop 2006; 130: 18-25. [Crossref]
28. Sung, JH, Kyung HM, Bae SM, Park HS, Kwon OW, McNamara JA. Microimplants in Orthodontics. Daegu: Dentos; 2006. p.12-3.
29. Buchter L, Wiechmann D, Koerdt S, Wiesmann HP, Piffko J, Meyer U. Load-related implant reaction of mini-implants used for orthodontic anchorage. Clin Oral Impl Res 2005; 16: 473-9. [Crossref]
30. Roberts WE, Marshall KJ, Mozsary PG. Rigid endosseous implant utilized as anchorage to protract molars and close an atrophic extraction site. Angle Orthod 1990; 60: 135-52. [Crossref]
31. Kanomi R. Mini-implant for orthodontic anchorage. J Clin Orthod 1997; 31: 763-7.
32. Yamaguchi M, Inami T, Ito K, Kasai K, Tanimoto Y. Mini-Implants in the anchorage armamentarium: New paradigms in the orthodontics. Int J Biomater 2012; 2012: 302825. [Crossref]
33. Li J, Li H, Shi L, Fok SLA, Ucer C, Devlin H, et al. A mathematical model for simulating the bone remodeling process under mechanical stimulus. Dent Mater 2007; 23: 1073-8. [Crossref]
34. Melsen B, Verna C. Miniscrew implants: The Aarhus anchorage system. Semin Orthod 2005; 11: 24-31. [Crossref]
35. Stahl E, Keilig L, Abdelgader I, Jager A, Bourauel C. Numerical analyses of biomechanical behaviour of various orthodontic anchorage implants. J Orofac Orthop 2009; 70: 115-27. [Crossref]
36. Baumgaertel S. Predrilling of the implant site: is it necessary for orthodontic mini-implants? Am J Orthod Dentofacial Orthop 2010; 137: 825-9. [Crossref]
37. Meijer GJ, Starmans FJM, de Putter C, Van Blitterswrjk CA. The influence of a flexible coating on the bone stress around dental implants. J Oral Rehabil 1995; 22: 105-11. [Crossref]
38. Barbier L, Sloten JV, Krzeinski G, Schepers E. Finite element analysis of non-axial versus axial loading of oral implants in the mandible of the dog. J Oral Rehabil 1998; 25: 847-58. [Crossref]
39. Clelland NL, Ismail YH, Zaki HS, Pipko D. Three-dimensional finite element stress analysis in and around the screw-vent implant. Int J Oral Maxillofac Implants 1991; 6: 391-2.
40. Vasquez M, Calao E, Becerra F, Becerra F, Ossa J, Enriquez C, et al. Initial stress difference between sliding and sectional mechanics with an endosseous implant as anchorage: A 3 dimensional finite element analysis. Angle Orthod 2001; 71: 247-56. [Crossref]
41. Jasmine MI, Yezdani AA, Tajir F, Venu RM. Analysis of stress in bone and microimplants during en-masse retraction of maxillary and mandibular anterior teeth with different insertion angulations: A 3-dimensional finite element analysis study. Am J Orthod Dentofacial Orthop 2012; 141: 71-80. [Crossref]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.19102

Original Article

Evaluation of Maxillofacial Characteristics in Individuals with Anterior Open Bite Using Denture Frame Analysis

Emre Cesur[1], Ayşegül Köklü[2]

[1]Department of Orthodontics, İstanbul Medipol University Faculty of Dentistry, İstanbul, Turkey
[2]Department of Orthodontics, Ankara University Faculty of Dentistry, Ankara, Turkey

Cite this article as: Cesur E, Köklü A. Evaluation of Maxillofacial Characteristics in Individuals with Anterior Open Bite Using Denture Frame Analysis. Turk J Orthod 2020; 33(3): 157-64.

ABSTRACT

Keywords: The aim of this study was to evaluate the effectiveness of denture frame analysis (DFA) in individuals with anterior open bite who had completed pubertal peak growth (post-peak).

Methods: This retrospective study was conducted using the cephalometric radiographs and hand-wrist X-rays of 50 individuals with open bite (mean age: 17.33±3 years; 35 female, 15 male) and a control group of 50 individuals without open bite (mean age: 17.38±2.72; 35 female, 15 male). All individuals included in the study were skeletal Class I and had completed or nearly completed skeletal growth. Skeletal and dental measurements pertaining to DFA were done and the data were analyzed using independent samples t test and Mann–Whitney U test.

Results: Measurements assessing the vertical dimension showed that GoGn/SN, Frankfurt horizontal (FH)/mandibular plane (MP), palatal plane (PP)/MP, occlusal plane (OP)/MP, and OP–MP/PP–MP measurements were significantly greater in the open bite group ($p<0.001$). AB/MP angle was significantly larger in the control group ($p<0.05$). The open bite group had shorter A'–P' (posterior maxillary length; $p<0.05$) and, therefore, higher A'–6'/A'–P' ratio ($p<0.01$).

Conclusion: Our results suggest that there may be a close association between maxillary OP inclination and mandibular position in individuals with open bite, and that open bite may arise due to maxillary denture base deficiency, especially in the posterior region. DFA may be useful in the differential diagnosis of open bite and in treatment planning, particularly when determining the need for tooth extraction.

Keywords: Denture frame analysis, occlusal plane, open bite, posterior discrepancy

Main points:

- Posterior arch length deficiency, particularly at the distal of the first molars can be present in individuals with open bite.
- Open bite may arise due to maxillary denture base deficiency.
- Mandibular position can be affected by the changes in the occlusal plane.

INTRODUCTION

Craniofacial growth estimation is important in orthodontics both in terms of diagnosis and treatment. Condylar growth has long been considered the primary factor affecting mandibular growth (1, 2). However, some studies suggest that condylar adaptation may arise as a result of mandibular repositioning and that changes in the position of the mandible may affect condylar growth (3, 4).

Cephalometric analyses usually examine the relationship of teeth with the cranial base and its effects on skeletal and soft tissue. In such skeletal and dental analyses, it is generally accepted that the impaired relationship between the maxilla and the mandible is caused by undesired growth pattern. However, the exact cause of excessive mandibular growth has not been established. It is still unclear whether the growth in condylar region is a result of genetic or adaptive effects. According to the functional matrix theory, skeletal units (i.e., the bony

Address for Correspondence: Emre Cesur, İstanbul Medipol University, Faculty of Dentistry, Department of Orthodontics, İstanbul, Turkey
E-mail: emre-cesur@hotmail.com

Received: November 18, 2020
Accepted: April 7, 2020
Available Online Date: August 7, 2020

structures that support and protect operational functional units) grow and adapt according to changes that occur in functional units (5-7).

Petrovic (8) investigated the growth of maxillofacial skeletal structures and described the "cybernetic model" based on Moss's concept. According to this model, mandibular position is largely affected by the functional needs, particularly articulation, and this is regulated by the central musculoskeletal system. Occlusal function is an important factor for mandibular growth. The displacement of the maxilla through forward and downward directs the growth of the mandible, and the mandible tries to adapt to this displacement functionally. In addition, the temporomandibular joint adapts to the new position of the mandible. According to the cybernetic theory, the functional factor regulating the mandibular growth is occlusal function. For example, functional occlusal planes (OPs) of an individual whose maxilla is developing downward will be located below and in response to this, the mandible will move vertically and develop in a vertical direction. The functional forces of the mandible will be transmitted through the temporal bone with the help of the temporomandibular joint and the masseter muscle, and movements or rotations will occur in the temporal bone. In addition, by changing the position of the mandible, the tensions of the lateral and medial pterygoid muscles change, causing the movement of sphenoid bone. The movement in the sphenoid bone changes the motion of the maxilla and affects the vertical position of the vomer. In short, the balance of the maxillofacial skeleton is affected by adapting the mandible to an abnormal occlusion with an abnormal growth pattern (9).

On the basis of this theory, Sato (10) claimed that the growth and morphology of the face was affected by the function of the occlusion and the OP. According to Sato et al. (11), the vertical positions of the posterior teeth do not stay stable during growth, especially in patients with open bite and/or high angle Class III. The OP is largely affected by its relationship with denture base deficiency posterior to the first molar. Posterior discrepancy results in the eruption of the molars during both the growth and post-pubertal period, which can also result in abnormal mandibular position and growth. The relationship of sagittal and vertical skeletal components with the occlusion should be taken into consideration while revealing the etiology of the malocclusion. Therefore, denture frame analysis (DFA) was introduced in 1987 by Sato. DFA is an easy diagnostic indicator that examines the structure of the lower face, including the skeletal frame of dentition, vertical component of the etiological factor, OP, and posterior insufficiency. It enables assessment and analysis of the vertical and sagittal relationship between the jaws and their associated OPs. DFA does not use the cranial reference planes, but is limited to the jaws and the teeth. Moreover, most cephalometric analyses based on cranial reference planes analyze vertical and sagittal relationships but overlook the fact that these two directions will affect one another (12-14). However, DFA allows evaluation of the relationships between facial type and OP, between anteroposterior problem and vertical component, and between changes in vertical dimensions and posterior insufficiency (15).

It is very difficult to control the vertical component of malocclusions. The most widely accepted and commonly used reference measurement in the evaluation of this component is the mandibular plane (MP) angle. However, the correlation between the MP angle and the vertical problem is not always sufficient for diagnosis and treatment planning (10). In their study, evaluating the norms of DFA in the Turkish population, Kayasu and Koklu (16) noted that their results differed from those obtained in the Japanese population and reported that differences may be observed based on sex and stage of skeletal maturity. Their results also demonstrated that DFA is very effective in establishing a differential diagnosis in the evaluation of the vertical dimension.

Therefore, the aim of this study was to evaluate the effectiveness of DFA as an adjunct to routinely used cephalometric analyses in order to enable occlusion-oriented evaluation for diagnosis, differential diagnosis, growth estimation, prognosis, and treatment planning in individuals with open bite who completed pubertal peak growth (post-peak). The null hypothesis of this study was "no difference exists between DFA measurements of individuals with and without open bite."

METHODS

We used GPower 3.1.0 software package (Universität Düsseldorf, Düsseldorf, Germany) to determine the number of individuals included in the study, and we further performed a power analysis. Based on a previous study, an expected effect size of f=0.56 was used in the power calculation (15). Sample size calculation was based on the ability to detect significant differences in A′–6′ and A′–P′ values at α=0.05 error probability (critical t: 1.664125; noncentrality parameter δ: 2.535508). According to power analysis, a sample size of 41 patients for each group would allow for a power >80 % (actual power: 0.807608) with an allocation ratio (N2/N1) =1.

Therefore, we analyzed the cephalometric radiographs and hand-wrist X-rays of 50 individuals with open bite (mean age: 17.33±3 years; 35 female, 15 male) and 50 individuals comprising the control group (mean age: 17.38±2.72; 35 female, 15 male) who presented to the Dentistry Hospital of the İstanbul Medipol University Mega Hospitals Complex and to the Ankara University Faculty of Dentistry for examination or treatment. The study was approved by the İstanbul Medipol University Ethics Committee (Approval No: 639) and conducted according to the principles set in the Declaration of Helsinki and informed consent was obtained from the patients.

Patients were included in the open bite group based on the following criteria:

1. Anterior open bite evident in patient photographs/clinical examination (overbite <0 mm).
2. Skeletal Class I (0°≤ANB≤4°) relationship, to rule out the anteroposterior differences.
3. Complete or near-complete skeletal development based on evaluation of hand-wrist radiographs (complete or near-complete fusion of radial epiphysis and diaphysis) (17, 18).
4. No missing teeth other than the third molars.
5. No craniofacial syndrome or congenital abnormalities.

Criteria 2 through 5 of the study group were also valid for the control group. Meanwhile, the individuals in the control group had overbite greater than 0 mm.

Profile distance X-rays of individuals included in the study were obtained using a Sirona Orthophos XG DS/Ceph X-ray device under standard conditions with teeth in maximum intercuspal position and the Frankfurt horizontal plane parallel to the ground. During imaging, the individual's sagittal plane was 155 cm from the X-ray source and 12.5 cm from the film cassette. Maximum distance between hand and X-ray source was used when acquiring the hand-wrist X-rays. AutoCAD 2016 (Autodesk, CA, USA) computer software was used for data analyses. Cephalometric landmarks used in the study are given in Table 1. The following standard cephalometric measurements were made (Figure 1):

1. SNA (posteroinferior angle between anterior cranial base and nasion-point A line), SNB (posteroinferior angle between anterior cranial base and nasion-point B line), ANB (angle between nasion-point A and nasion-point B lines), and GoGn/SN (angle between anterior cranial base and Go-Gn line) angles.
2. Overjet (the horizontal distance between the maxillary and mandibular incisors) and overbite (the vertical distance between the maxillary and mandibular incisors).

Measurements used in the DFA were as follows (Figure 2) (10, 11):

1. Frankfurt horizontal (FH)/MP (angle between FH line [Po–Or] and MP [Go–Me]), palatal plane (PP)/MP (angle between PP [anterior nasal spine (ANS)– posterior nasal spine (PNS)] and MP), OP/MP (angle between the maxillary OP [U1i–U6] and MP), AB/MP (angle between the line connecting A and B points and MP), A′–6′ (anterior maxillary length; distance between point A′ and point 6′), and A′–P′ (maxillary length; distance between point A′ and point P′).
2. U1i–AB (perpendicular distance from incisal point of upper incisor to AB line), U1/AB (acute angle between axis of upper incisor, U1i–U1a, and AB line), L1i–AB (perpendicular distance from incisal point of lower incisor to AB line), L1/AB (acute angle between axis of upper incisor, L1i–L1a, and AB line), and intermolar angle (wide angle between long axis of upper and lower first molars).

Statistical Analysis

Measurements were performed twice by the same observer four weeks apart and correlation coefficients were calculated to assess reliability of the measurements. Data obtained in the study were analyzed with The Statistical Package for Social Sciences version 21.0 software (IBM Corp.; Armonk, NY, USA). Comparisons between two groups were done using independent samples t -test or Mann–Whitney U test in accordance with tests of normality. Level of significance was accepted as 0.05; $p<0.05$ were considered statistically significant.

Table 1. Cephalometric skeletal and dental landmarks

	Skeletal Landmarks
Nasion (N)	The most anterior point of the frontonasal suture
Sella (S)	The midpoint of sella turcica
A	The deepest point of the concavity on the maxilla between ANS and prosthion
B	The deepest point of the concavity on the mandibular symphysis between infradentale and pogonion
Gonion (Go)	Point of intersection of the ramus plane and the mandibular plane
Gnathion (Gn)	The most anteroinferior point on the symphysis
Menton (Me)	The midpoint on the inferior border of the mental protuberances
ANS	The most anterior point of anterior nasal spine
PNS	The most posterior point of posterior nasal spine
Orbitale (Or)	The most antero-inferior point of the infraorbital rim
Porion (Po)	The most superior point of the meatus acusticus externus
Pterygomaxillary fissure (P)	The most anterior point of the pterygomaxillary fissure
A′	Projection of point A on palatal plane (ANS-PNS line)
P′	Projection of point P on palatal plane (ANS-PNS line)
	Dental Landmarks
U1i	Incisal point of upper central incisor
U1a	Apical point of upper central incisor
L1i	Incisal point of lower central incisor
L1a	Apical point of lower central incisor
U6	The midpoint of upper first molar's occlusal surface
U6f	Furcation point between upper first molar's mesial and distal roots
L6	The midpoint of lower first molar's occlusal surface
L6f	Furcation point between lower first molar's mesial and distal roots
U6m	The most anterior point of upper first molar crown
6′	Projection of U6m on the palatal plane (ANS-PNS line)

RESULTS

Repeated measurements showed high reliability, with correlation coefficients ranging between 0.882 and 0.996.

Comparison of mean values in the open bite and control group showed that the ANB angle was 2° in the open bite group and 2.6° in the control group (p<0.05). Measurements assessing the

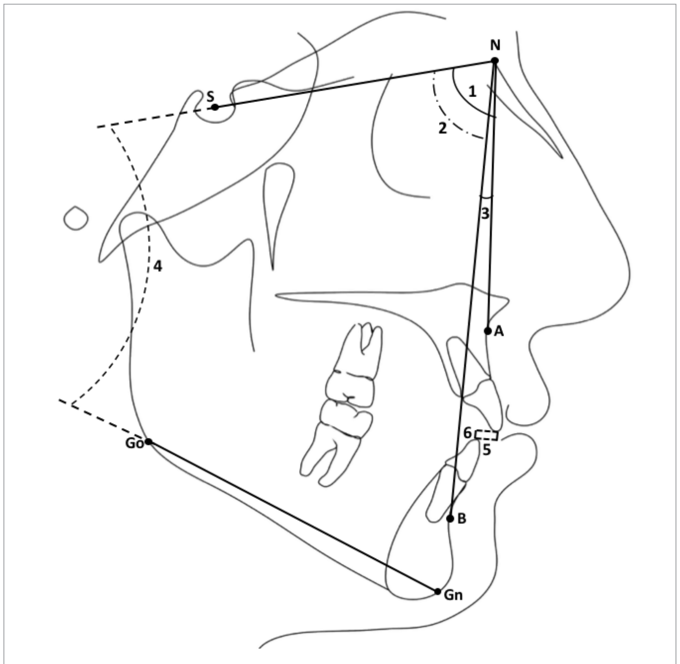

Figure 1. Standard cephalometric measurements used in the study: 1. SNA, 2. SNB, 3. ANB, 4. Go-Gn/SN, 5. Overjet 6. Overbite

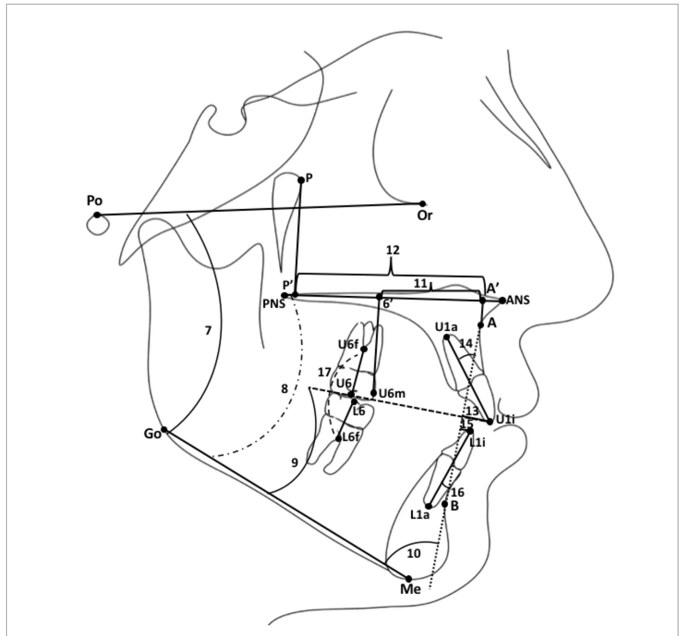

Figure 2. DFA measurements: 7. FH/MP 8. PP/MP 9. OP/MP 10. AB/MP 11. A'-6', 12. A'-P', 13. U1i-AB, 14. U1/AB 15. L1i-AB, 16. L1/AB, 17. Intermolar angle

Table 2. Descriptive statistics and comparison of the cephalometric measurements between the open bite and control groups with t test

	Open Bite Group			Control Group			t test	
	n	Mean	±SD	n	Mean	±SD	t	p
Chronological Age	50	17.33	3.00	50	17.38	2.72	-0.072	0.943
Standard Cephalometric Measurements								
SNA (°)	50	79.3	4.3	50	80.2	3.3	-1.202	0.232
SNB (°)	50	77.2	4.7	50	77.6	3.6	-.457	0.649
ANB (°)	50	2.0	1.3	50	2.6	1.2	-2.174	0.032*
GoGn/SN (°)	50	37.6	5.7	50	30.4	5.4	6.397	0.000***
Overjet (mm)	50	2.50	2.05	50	3.25	1.23	-2.217	0.029*
Overbite (mm)	50	-2.64	2.21	50	2.18	1.28	-13.317	0.000***
Denture Frame Analysis Measurements								
FH/MP (°)	50	30.3	5.1	50	22.6	4.8	7.815	0.000***
PP/MP (°)	50	30.9	5.6	50	22.7	6.3	6.899	0.000***
OP/MP (°)	50	21.9	4.8	50	13.3	4.0	9.646	0.000***
OP-MP/PP-MP	50	0.71	0.11	50	0.56	.13	6.140	0.000***
AB/MP (°)	50	65.6	5.3	50	74.3	4.4	-8.949	0.000***
A'-6' (mm)	50	21.79	2.34	50	21.06	2.20	1.621	0.108
A'-P' (mm)	50	42.84	3.65	50	44.37	3.31	-2.210	0.029*
A'-6'/A'-P'	50	0.51	0.06	50	0.47	.05	3.220	0.002**
U1-AB (mm)	50	7.04	2.28	50	6.32	2.23	1.594	0.114
U1/AB (°)	50	30.5	6.6	50	28.8	7.3	1.175	0.243
L1-AB (mm)	50	5.10	4.46	50	3.10	1.81	2.939	0.004**
L1/AB (°)	50	24.4	6.0	50	22.1	6.3	1.898	0.061
Intermolar Angle (°)	50	168.0	6.9	50	172.4	6.8	-3.236	0.002**

* p<0.05, ** p<0.01, *** p<0.001, SD: Standard deviation

vertical dimension showed that GoGn/SN, FH/MP, PP/MP, OP/MP, and OP-MP/PP-MP measurements were significantly greater in the open bite group (p<0.001). AB/MP angle was significantly larger in the control group (p<0.05). The open bite group had shorter A'–P' (maxillary length) (p<0.05) and consequently higher A'–6'/A'–P' ratio (p<0.01). Intermolar angle, overjet, and overbite were found to be greater in the control group (Table 2).

When the groups were compared by sex, females in the open bite and control groups showed significant differences in ANB angle, GoGn/SN, FH/MP, PP/MP, OP/MP, OP–MP/PP–MP, AB/MP, A'–P', L1–AB, intermolar angle, overjet, and overbite, whereas males in the open bite and control groups showed significant differences in terms of ANB angle, GoGn/SN, FH/MP, PP/MP, OP/MP, OP-MP/PP–MP, AB/MP, A'–6', A'–6'/A'–P' ratio, L1–AB, L1/AB, intermolar angle, and overbite (Table 3).

According to sex-based comparisons within each group, only A'–P' was higher in males than females in the open bite group (p<0.05). In the control group, females had higher PP/MP value and A'–6'/A'–P' ratio compared to the males (p<0.05; Table 4).

DISCUSSION

Although cephalometric radiographs are widely used in orthodontics to evaluate the growth and development of facial structures and treatment-induced changes in these structures, these analyses are generally inadequate to detect the change between these facial structures and the OP. According to Sato (10) the growth and morphology of the face was affected by the function of the occlusion and the OP. Citing the lack of an analysis that demonstrated the relationship between facial type and OP, between anteroposterior problem and the vertical component, or between changes in vertical dimensions and posterior deficiency in the dental arch, Sato (10) developed DFA to understand the relationship between posterior deficiency, the OP, and mandibular repositioning. Changes in the posterior OP play an important role not only in the sagittal dimension but also in the vertical dimension and position of the maxillomandibular structures (19, 20). The tooth-to-denture base discrepancy posterior to the first molar causes a "squeezing out" effect, the occlusal contacts that occur due to the crowding of the maxillary molars cause changes in mandibular position, and abnormal vertical mandibular growth may lead to open bite (11, 19).

On the basis of these considerations, in this study comparing OP and craniofacial morphology in individuals with and without open bite using DFA, we matched two groups in terms of chronological age and sex distribution in order to minimize intergroup differences. When selecting the study sample, we considered not only chronological age but also stage of skeletal development. It is known that normative values may be affected by growth and development and can change in later stages (21). Thus, to avoid

Table 3. Comparison of the cephalometric measurements between the open bite and control group for females and males Mann Whitney U test

	Female					Male				
	Open Bite (n:35)		Control (n:35)			Open Bite (n:15)		Control (n:15)		
	Mean	±SD	Mean	±SD	p	Mean	±SD	Mean	±SD	p
Chronological Age (year)	17.87	3.16	17.35	2.93	0.507	16.08	2.17	17.44	2.26	0.089
Standard Cephalometric Measurements										
SNA (°)	79.2	4.3	80.0	3.5	0.528	79.5	4.4	80.7	2.9	0.371
SNB (°)	77.2	4.6	77.3	3.8	0.887	77.3	5.0	78.4	3.0	0.371
ANB (°)	2.0	1.3	2.7	1.1	0.017*	2.2	1.4	2.4	1.4	0.746
GoGn/SN (°)	37.4	6.1	31.5	4.5	0.0001***	38.0	5.0	28.0	6.7	0.0001***
Overjet (mm)	2.66	2.08	3.33	1.31	0.033*	2.12	1.98	3.04	1.04	0.164
Overbite (mm)	-2.44	1.95	2.01	1.17	0.0001*	-3.10	2.76	2.57	1.48	0.0001***
Denture Frame Analysis Measurements										
FH/MP (°)	29.7	5.4	23.0	3.9	0.0001***	31.6	3.8	21.7	6.4	0.0001***
PP/MP (°)	30.3	5.0	24.5	3.7	0.0001***	32.3	6.9	18.6	8.9	0.0001***
OP/MP (°)	21.3	4.2	13.6	3.5	0.0001***	23.3	5.9	12.7	5.0	0.0001***
OP-MP/PP-MP	0.70	0.11	0.55	0.11	0.0001***	0.72	.11	.57	0.17	0.018**
AB/MP (°)	65.7	4.7	74.2	3.9	0.0001***	65.3	6.7	74.6	5.7	0.001**
A'-6' (mm)	21.46	2.08	21.25	2.09	0.747	22.56	2.78	20.61	2.44	0.036*
A'-P' (mm)	42.09	3.08	43.80	3.33	0.038*	44.57	4.35	45.71	2.93	0.694
A'-6'/A'-P'	0.51	0.06	0.48	0.05	0.069	0.51	0.08	0.45	0.04	0.011*
U1-AB (mm)	7.18	2.33	6.55	2.27	0.408	6.72	2.23	5.77	2.11	0.213
U1/AB (°)	29.9	6.3	29.6	7.4	0.685	31.9	7.4	27.1	7.1	0.092
L1-AB (mm)	5.35	5.20	3.25	1.81	0.007**	4.51	1.83	2.73	1.82	0.026*
L1/AB (°)	24.5	6.5	23.0	6.3	0.154	24.3	4.9	19.9	6.2	0.048*
Intermolar Angle (°)	167.7	7.5	171.5	6.9	0.023*	168.7	5.4	174.5	6.3	0.004**

* p<0.05, ** p<0.01, *** p<0.001, SD: Standard deviation

Table 4. Intragroup comparison of the cephalometric measurements between the sexes using with Mann Whitney U test

	Female					Male				
	Open Bite (n:35)		Control (n:35)			Open Bite (n:15)		Control (n:15)		
	Mean	±SD	Mean	±SD	p	Mean	±SD	Mean	±SD	p
Chronological Age (year)	17.87	3.16	16.08	2.17	0.057	17.35	2.93	17.44	2.26	0.719
Standard Cephalometric Measurements										
SNA (°)	79.2	4.3	79.5	4.4	0.841	80.0	3.5	80.7	2.9	0.333
SNB (°)	77.2	4.6	77.3	5.0	0.992	77.3	3.8	78.4	3.0	0.118
ANB (°)	2.0	1.3	2.2	1.4	0.586	2.7	1.1	2.4	1.4	0.464
GoGn/SN (°)	37.4	6.1	38.0	5.0	0.664	31.5	4.5	28.0	6.7	0.063
Overjet (mm)	2.66	2.08	2.12	1.98	0.391	3.33	1.31	3.04	1.04	0.657
Overbite (mm)	-2.44	1.95	-3.10	2.76	0.561	2.01	1.17	2.57	1.48	0.223
Denture Frame Analysis Measurements										
FH/MP (°)	29.7	5.4	31.6	3.8	0.256	23.0	3.9	21.7	6.4	0.618
PP/MP (°)	30.3	5.0	32.3	6.9	0.318	24.5	3.7	18.6	8.9	0.021*
OP/MP (°)	21.3	4.2	23.3	5.9	0.246	13.6	3.5	12.7	5.0	0.438
OP-MP/PP-MP	0.70	0.11	0.72	0.11	0.799	0.55	0.11	0.57	0.17	0.849
AB/MP (°)	65.7	4.7	65.3	6.7	0.865	74.2	3.9	74.6	5.7	0.932
A'-6' (mm)	21.46	2.08	22.56	2.78	0.071	21.25	2.09	20.61	2.44	0.485
A'-P' (mm)	42.09	3.08	44.57	4.35	0.018*	43.80	3.33	45.71	2.93	0.072
A'-6'/A'-P'	0.51	0.06	0.51	0.08	0.899	.48	0.05	0.45	0.04	0.009**
U1-AB (mm)	7.18	2.33	6.72	2.23	0.518	6.55	2.27	5.77	2.11	0.216
U1/AB (°)	29.9	6.3	31.9	7.4	0.304	29.6	7.4	27.1	7.1	0.379
L1-AB (mm)	5.35	5.20	4.51	1.83	0.657	3.25	1.81	2.73	1.82	0.285
L1/AB (°)	24.5	6.5	24.3	4.9	0.815	23.0	6.3	19.9	6.2	0.135
Intermolar Angle (°)	167.7	7.5	168.7	5.4	0.832	171.5	6.9	174.5	6.3	0.071

* p<0.05, ** p<0.01; SD: Standard deviation

variation in our results related to stage of skeletal development, all individuals selected for the study had completed or nearly completed growth (17, 18). Although there was a significant difference between the open bite group and control group in terms of ANB angle ($p<0.05$), we made sure to select the individuals included in both groups from among those with skeletal Class I relationship in order to limit the effect of the sagittal dimension and to better evaluate the vertical dimension (open bite group ANB: 2°, control group ANB: 2.6°). Consistent with ANB angle, we found that among the individuals included in our study, overjet was also slightly greater in the control group and the difference was significant between the females in the two groups ($p<0.05$).

Skeletal open bite is not limited to the dentoalveolar region alone but includes craniofacial malformations that involve the skeletal structure and jaws (22, 23). In this study,the evaluation of parameters related to the vertical dimension (GoGn/SN, FH/MP, and PP/MP) naturally revealed significant differences between the open bite and control groups, with the open bite group displaying a larger MP angle ($p<0.001$). Although sex-based comparisons between the groups yielded similar results, intragroup comparisons between the sexes showed that only PP/MP angle was larger in females than males in the control group, whereas no differences were detected in other measurements. In DFA, the angle between AB and MP is analyzed to evaluate the relationship between the maxilla and the mandible in the sagittal plane. Although this measurement provides insight into both horizontal and vertical jaw relation, Celar et al. (15) stated that this parameter alone is inadequate for the evaluation of the relationship between the maxilla and the mandible. In our study, this angle was significantly narrower in the open bite group and the difference was significant for both females and males in sex-based comparisons between the groups. We attribute this difference to the steeper MP in the open bite group rather than anteroposterior differences. AB-MP angle gives the relation of the jaws in the sagittal direction. However, as this angle also depends on the inclination of the mandibular plane, it is a measurement that evaluates the sagittal and vertical positions simultaneously. Therefore, the use of this measurement without considering vertical parameters is not appropriate for determining the anteroposterior relationship of jaws.

Occlusion and the maxillofacial structures comprise a unique and dynamic mechanism involving continuous interaction. Therefore, orthodontic treatment does not simply alter occlusion, but also changes the skeletal structures of maxillofacial structures. According to Petrovic (24), there is a direct relationship between occlusion and mandibular position. He stated that differences in the direction and amount of the condylar growth can arise in response to changes in maxillary length, and that the lower dental arch can be controlled through the continuously changing reference inputs of the upper dental arch. In DFA, the angle between the maxillary OP and MP demonstrates the functional adaptation capacity of the mandible, while the OP–MP/PP–MP ratio shows the ratio of the angle between MP and maxillary OP to the angle between MP and PP. Normally, in order to maintain a stable OP/MP angle, the mandible changes its position in accordance with the occlusal function. However, the mandible cannot adapt to excessive changes in the OP and undergoes posterior rotation, increasing this angle. An OP-MP/PP-MP ratio over 0.6 indicates a deviation in the OP that the mandible could not adapt to. The increase in this ratio is the suggestive of an open bite (10). The evaluation of these parameters in the present study showed that OP/MP angle was higher in the open bite group, while the OP-MP/PP-MP ratio was 0.71, corroborating Sato's predictions. This ratio was significantly greater for both females and males in the open bite group compared to the control group. Celar et al. (15) reported an OP-MP/PP-MP ratio of 0.56 and a mean of 0.7 in open bite, whereas Sato (10) found this ratio to be 0.54 in the normal individuals. Although the increase in the angle of the MP can affect these values, the results obtained in the present study confirm these results and indeed suggest that the mandibular position can be affected by the changes in the OP.

Sato (10) stated that if there is crowding in the posterior jaw, molars will try to create room through mesialization; if this is not sufficient, the molars will sag and cause flattening of the OP. If the mandible has growth potential, it can overcome these posterior contacts with growth in the anterior aspect. If it does not have enough growth potential, open bite will occur. In DFA, A'–P' distance is evaluated to determine the total length of the maxillary denture base, whereas anterior maxillary base length is evaluated by measuring A'–6'. Decrease in total maxillary length and/or increase in A'–6' length increases the probability of posterior deficiency. A'–6'/A'–P' ratio represents the proportion of the anterior base (from anterior teeth to first molar) within the entire maxillary dental arch. Higher ratio indicates shorter posterior region and potential need for space. In our study, when these measurements were analyzed, we observed that A'–P' distance was shorter and A'–6'/A'–P' ratio was higher in individuals with open bite. This indicates that posterior arch length deficiency, particularly at the distal of the first molars in anteroposterior dimension, can indeed be present in individuals with open bite. According to Sato and Suzuki (25), one of the reasons for superiority of DFA is that it can facilitate differential diagnosis and guide the decision to perform tooth extraction in cases of tooth-to-denture base discrepancy. Similarly, Celar et al. (15) stated that this ratio can be used to determine whether to perform molar distalization or tooth extraction to resolve tooth crowding. Kim (26) reported that in patients with steepened mandibular and palatal planes and relatively reduced posterior lower facial height, the molars become mesially inclined and their contacts prevent the contact of the anterior teeth. They stated that tooth straightening and/or extraction is required to eliminate this blockage. According to DFA, molars are the most stable centric stops when forces are applied vertically. However, in cases of posterior crowding, mesial tipping of the molars is observed. This tipping causes the angle between the molars to decrease (10, 11). In accordance with these studies, our evaluation demonstrated smaller intermolar angle in the open bite group compared to the control group.

Other dentoalveolar measurements that were used in our study and indicate incisor position were also based on DFA. Accordingly, we assessed the distance and angle of the maxillary and mandibular incisors to the AB line. The measurements revealed only protrusion of the lmandibular incisors in the open bite group compared to the control group. However, an important point to consider regarding these measurements is that the results may be affected by the positions of skeletal points A and B. In individuals with open bite, it must be kept in mind that with the posterior rotation of the mandible, point B may be positioned more posteriorly, which may give the impression of mandibular incisor protrusion. We believe the measurements that evaluate tooth positions independent from skeletal variations may be more useful than the dental measurements performed in this analysis.

CONCLUSION

Null hypothesis was rejected. Our results suggest that there may be a close association between OP inclination and mandibular position in individuals with open bite, and that open bite may arise due to maxillary denture base deficiency, particularly in the posterior region.

Accordingly, DFA can be useful in the differential diagnosis of open bite and in treatment planning, particularly when determining the need for tooth extraction. However, drawbacks such as lack of soft tissue visualization and inadequacy in determining tooth positions require DFA to be used in combination with other analyses.

Ethics Committee Approval: EThis study was approved by Ethics committee of İstanbul Medipol University (Approval No: 639).

Informed Consent: Verbal informed consent was obtained from the patients.

Peer-review: Externally peer-reviewed.

Author Contributions: Design – E.C., A.K.; Supervision – A.K.; Resources – E.C., A.K.; Materials – E.C., A.K.; Data Collection and/or Processing – E.C.; Analysis and/or Interpretation – E.C.; Literature Search – E.C.; Writing Manuscript – E.C.; Critical Review – A.K.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Björk A. Variations in the growth pattern of the human mandible: longitudinal radiographic study by the implant method. J Dent Res 1963; 42: 400-11. [Crossref]
2. McNamara JA Jr, Carlson DS. Quantitative anaysis of temporomandibular joint adaptation to protrusive function. Am J Orthod 1979; 76: 593-611. [Crossref]
3. Tanaka ME, Sato S. Longitudinal alteration of the occlusal plane and development of different dentoskeletal frames during growth. Am J Orthod Dentofac Orthop 2008; 134: 602.e1-11. [Crossref]

4. Kim JI, Hiyama T, Akimoto S, Shinji H, Tanaka EM, Sato S. Longitudinal study regarding relationship among vertical dimension of occlusion, cant of occlusal plane and antero-posterior occlusal relation. Bull Kanagawa Dent Coll 2006; 34: 130-2.
5. Moss ML. The primacy of functional matrices in orofacial growth. Dent Pract Dent Rec 1968; 19: 65-73.
6. Moss ML, Rankow RM. The role of the functional matrix in mandibular growth. Angle Orthod 1968; 38: 95-103.
7. Moss ML, Salentijn L. The primary role of functional matrices in facial growth. Am J Orthod 1969; 55: 566-77. [Crossref]
8. Petrovic A. Control of postnatal growth of secondary cartilages of the mandible by mechanisms regulating occlusion. Cybernetic model. Trans Eur Orthod Soc 1974: 69-75.
9. Slavicek R. The Masticatory Organ. 1st ed. Klosterneuburg (Austria): GAMMA Medizinisch-wissenschaftliche Fortbildung-AG; 2002.
10. Sato S. Alteration of occlusal plane due to posterior discrepancy related to development of malocclusion. Introduction to Denture Frame Analysis. Bull Kanagawa Dent Col 1987; 15: 115-23.
11. Sato S, Suzuki N, Suzuki Y. Longitudinal study of the cant of the occlusal plane and the denture frame in cases with congenitally missing third molars. Further evidence for the occlusal plane change related to the posterior discrepancy. Nihon Kyosei Shika Gakkai Zasshi 1988; 47:517-25.
12. Schudy FF. Cant of occlusal plane and axial inclinations of teeth. Angle Orthod 1963; 33: 69-82.
13. Sassouni VA. A classification of skeletal facial types. Am J Orthod 1969; 55: 109-23. [Crossref]
14. Moss ML. Beyond roentgenographic cephalometry--what? Am J Orthod 1983; 84: 77-9. [Crossref]
15. Celar AG, Freudenthaler JW, Celar RM, Jonke E, Schneider B. The denture frame analysis: an additional diagnostic tool. Eur J Orthod 1998; 20: 579-87. [Crossref]
16. Kayasu T, Köklü A. Denture Frame Analizi'nin Toplumumuzdaki Normlari Ve Vertikal Yön Etkinliği. Ankara Üniversitesi Sağlık Bilimleri Enstitüsü, Doktora Tezi. 2012.
17. Helm S, Nielsen SS, Skieller V, Björk A. Skeletal maturation of the hand in relation to maximum puberal growth in body height. Tandlaegebladet 1971; 75: 1223-34.
18. Greulich WW, Pyle SI. Radiographic atlas of skeletal development of hand and wrist. 2nd ed. Stanford: Stanford University Press; 1959. [Crossref]
19. Sato S, Sasaguri K, Kamoi S, Goto M, Suzuki Y. Importance of posterior tooth-to-denture base discrepancy in the development of skeletal open bite malocclusion. Nihon Kyosei Shika Gakkai Zasshi 1990; 49: 322-30.
20. Fushima K, Kitamura Y, Mita H, Sato S, Suzuki Y, Kim YH. Significance of the cant of the posterior occlusal plane in class II division 1 malocclusions. Eur J Orthod 1996; 18: 27-40. [Crossref]
21. Uzel İ, Enacar A. Ortodontide Sefalometri. 2nd ed. Adana: Çukurova Üniversitesi Basımevi; 2000.
22. Nahoum HI. Vertical proportions and palatal plane in anterior openbite. Am J Orthod 1971; 59: 273-82. [Crossref]
23. English JD, Olfert KDG. Masticatory muscle exercise as an adjunctive treatment for open bite malocclusions. Semin Orthod 2005; 11: 164-9. [Crossref]
24. Petrovic A. Experimental and cybernetic approaches to the mechanism of action of functional appliances on mandibular growth. McNamara, JA Jr, Ribbens KA, editors. Malocclusion and the periodontium. Ann Arbor: Monograph 15, Craniofacial Growth Series. Center for Human Growth and Development, USA: University of Michigan; 1984.p.213-68.
25. Sato S, Suzuki Y. Relationship between the development of skeletal mesio-occlusion and posterior tooth-to-denture base discrepancy. Nihon Kyosei Shika Gakkai Zasshi 1988; 47: 796-810.
26. Kim YH. Anterior open-bite and its treatment with multiloop edgewise archwire. Angle Orthod 1987; 57: 290-321.

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.19049

Original Article

Orthodontic Bond Strength Comparison between Two Filled Resin Sealants

James Anthony Kolstad[1], Danielle Lynn Cianciolo[2], Alan James Ostertag[3], David William Berzins[4]

[1]Orthodontic Resident, Department of Developmental Sciences, Marquette University School of Dentistry, Milwaukee, Wisconsin, USA
[2]Marquette University School of Dentistry, Milwaukee, Wisconsin, USA
[3]Private Practice, Eau Claire, Wisconsin, USA
[4]General Dental Sciences, Marquette University School of Dentistry, Milwaukee, Wisconsin, USA

Cite this article as: Kolstad JA, Cianciolo DL, Ostertag AJ, Berzins DW. Orthodontic Bond Strength Comparison between Two Filled Resin Sealants. Turk J Orthod 2020; 33(3): 165-70.

Main points:

- Sealants are effective in reducing demineralization during orthodontic treatment, but they should not compromise the bond between brackets and teeth.
- The bond strength of the two commercial sealants was compared with that of a traditional primer.
- Although the sealants generally had lower bond strengths than the control, their bond strengths were clinically acceptable.

ABSTRACT

Objective: Sealants are used in orthodontics to help prevent demineralization during treatment. This study aimed to determine if there is a difference in the shear bond strength (SBS) between 2 different resin sealants bonded to teeth.

Methods: Extracted human premolars (n=20/group) were randomly divided and prepared by acid etching, followed by application of primer or sealant. Group 1, the control group, used Transbond XT Primer (3M Unitek). Groups 2 and 3 were prepared with the sealants L.E.D. Pro Seal (Reliance Orthodontic Products) and Opal Seal (Opal Orthodontics) as the respective primers. Transbond XT Adhesive was applied to a stainless steel bracket and bonded to each tooth. Each group was stored in distilled water at 37°C for 48 hours before. SBS was measured using a universal testing machine, and the adhesive remnant index (ARI) was scored.

Results: The SBS (MPa) of the groups was as follows: Group 1 (Transbond): 20.1±6.0; Group 2 (Pro Seal): 16.5±4.8; and Group 3 (Opal Seal): 15.7±3.9. The SBS of Transbond XT Primer was significantly greater than that of Opal Seal ($p<0.05$/analysis of variance-Tukey), while Pro Seal and Opal Seal sealants were not significantly different from each other ($p<0.05$). The Opal Seal group had significantly greater ARI scores, indicating that more adhesive remained on the teeth after debonding.

Conclusion: Opal Seal and Pro Seal sealants have similar SBS but generally exhibit lower bond strengths than an adhesive primer.

Keywords: Adhesive remnant index, bond strength, orthodontic sealant

INTRODUCTION

A common problem in orthodontic treatment is the formation of white spot lesions or enamel decalcification on the tooth. The prevalence of white spot lesions in orthodontic patients has been shown to be 34%–97%, whereas the incidence of such lesions during orthodontic therapy has been shown to be 23%–76% (1). White spot lesions are considered to be unhealthy, irreversible, and unesthetic (2-4). Patients, parents, orthodontists, and dentists agree that white spot lesions detract from the overall appearance of the orthodontic patient, and the patient is primarily responsible for the prevention of these lesions (4). Nevertheless, white spot lesions are easily detectable and can be arrested by preventive treatment or even prevented altogether (5).

Over the years, orthodontists have tried many different ways to prevent enamel demineralization in their patients (2, 3, 5-11). Prevention methods have included oral hygiene instruction, fluoride mouth rinses, application

Address for Correspondence: David William Berzins, General Dental Sciences, Marquette University School of Dentistry, Milwaukee, Wisconsin, USA
E-mail: david.berzins@marquette.edu

Received: April 26, 2019
Accepted: May 25, 2020
Available Online Date: August 7, 2020

Turk J Orthod 2020; 33(3): 165-70

of fluoride varnishes, and sealants. All the preventive methods, other than fluoride varnish and sealants, require patient compliance during treatment (2). It has been shown that a relationship may exist between patient compliance and the formation of white spot lesions (4, 5, 11). One way to combat the need for patient compliance and reduce decalcification is the application of a sealant on the facial aspect of the tooth before bonding the bracket (3, 9). Opal Seal (Opal Orthodontics, South Jordan, UT, USA) and L.E.D. Pro Seal (Reliance Orthodontic Products, Itasca, IL, USA) are two different brands of orthodontic sealants.

Pro Seal is described by the manufacturer as a fluoride-containing, light-cured filled sealant that completely sets without an oxygen-inhibited layer, creating a smooth and hard surface that prevents leakage and protects the enamel (12). Opal Seal is 38% filled with proprietary glass ionomer fillers and nanofillers and is also light-curable and contains fluoride (13). Both the sealants contain a fluorescing agent that can be illuminated by a black light to determine whether the sealant is still present on the tooth surface (12, 13). Recent independent *in vitro* studies have evaluated Pro Seal and Opal Seal sealants for their surface, mechanical, and esthetic properties (3, 7, 10). Results from these studies have shown that each sealant may have advantages over the other. Opal Seal was found to be significantly harder, allowed less *Streptococcus mutans* adherence, and had better color stability (7, 10). In contrast, Pro Seal was found to be more wear-resistant and released significantly greater amounts of fluoride (7, 10). In terms of efficacy, both Pro Seal and Opal Seal sealants provide reductions in enamel demineralization compared with the untreated controls (3, 6, 14).

Understanding the different properties of each product along with their bond strength can play an important role in deciding which product to use clinically. Although some of the physical and esthetic properties of each sealant have been compared with each other, their orthodontic bond strengths have not been compared. Research has been conducted to investigate the bond strength of Pro Seal sealant bonded with different adhesives (5, 9, 15-18). For example, Lowder et al. (9) found that Pro Seal sealant produced clinically acceptable bond strengths when coupled with four different adhesives, but its bond strength was lower than two regular primer/adhesive systems. Comparatively, the bond strength of Opal Seal sealant has not been investigated as thoroughly (19). This study aimed to compare the shear bond strength (SBS) between two different resin sealants when used to bond orthodontic brackets to teeth. The null hypothesis was that there would be no difference in SBS between Pro Seal and Opal Seal.

METHODS

Following the Institutional Review Board clearance (Approval No: DT-027), 60 human premolar teeth extracted for orthodontic reasons were collected and stored in distilled water at 4°C. Each patient or parent for a minor patient signed a consent form allowing for their teeth to be used for research purposes. The extracted teeth possessed no identifying information; therefore, the age of the patient was not known to the researchers. However, the teeth consisted of upper and lower, first and second premolars. The distilled water was refreshed periodically to limit bacterial growth, and the time required to collect all necessary teeth was 6 months. If any large restorations, enamel defects, or any abnormal flaws were found on examination, the tooth was excluded. The roots were removed from each tooth with a high-speed handpiece and diamond bur. The cut was made about 6 mm below the cementoenamel junction. Each crown was then placed back into a container of distilled water at 4°C.

The teeth were randomly divided into 3 groups (n=20/group). Randomization was achieved by mixing the 60 extracted premolars and blindly selecting the teeth to comprise each group in a parallel manner (tooth 1 for each group sequentially to tooth 20 for each group). Group 1 was bonded with Transbond XT Primer (3M Unitek, Monrovia, CA, USA) and Transbond XT light cure adhesive (3M Unitek). Group 2 was bonded with L.E.D. Pro Seal sealant and Transbond XT adhesive. Group 3 was bonded with Opal Seal sealant and Transbond XT Adhesive. Stainless steel brackets (universal upper bicuspid, Victory Series, 3M Unitek) with zero torque and tip were used. The surface area of the bracket base was 10 mm^2.

Before the bonding procedure, each tooth was cleaned with a rubber prophy cup on a slow-speed handpiece with pumice paste (Nada, Preventive Technologies, Inc., Indian Trail, NC, USA) for 5 seconds and then rinsed with water. The tooth was then etched using 35% phosphoric acid etching gel (3M Unitek) for 30 seconds and was thoroughly rinsed and dried until the etched buccal surface appeared frosty white. For each group, the primer or sealant (Transbond XT Primer, Pro Seal, and Opal Seal for Groups 1-3, respectively) was applied to the buccal surface of the tooth following manufacturer instructions. Transbond XT Adhesive was then applied to the bracket base. The bracket was placed in the proper position on the tooth and was pressed firmly to seat the bracket. The excessive resin was removed, and the adhesive was light-cured (Ortholux Luminous Curing Light, 3M Unitek) for 10 seconds on both the mesial and distal aspects of the bracket. One operator prepared all the teeth. The tooth with the bonded bracket was then placed back into the appropriate container of distilled water and stored at 37°C for 24 hours.

After storage, the teeth were individually mounted in cold-cure acrylic (Great Lakes Orthodontics, Tonawanda, NY, USA). Each tooth was attached to a 0.018-inch stainless steel wire using an elastomeric module and suspended over a small section of polyvinyl chloride pipe. The acrylic was mixed and poured into the pipe to the level of the cusp tip of the suspended tooth, assuring each tooth was mounted in the acrylic in a repeatable way. After the acrylic set, each bonded and mounted tooth was placed back into distilled water and stored at 37°C for 24 hours.

A universal testing machine (Instron, Norwood, MA, USA) was used to measure the SBS of each bracket/tooth specimen. Each mounted tooth was secured in a fixture that allowed a blade attached to the machine crosshead to contact the bracket between its base and gingival tie wings (Figure 1). A shear force

Table 1. Shear bond strength and Weibull analysis

Group	Mean±standard deviation (MPa)*	Weibull modulus (β)	Characteristic strength (α; MPa)	Shear bond strength (MPa) at 10% probability of failure	Shear bond strength (MPa) at 90% probability of failure
1-Transbond	20.1±6.0	3.4	22.2	11.4	28.4
2-Pro Seal	16.5±4.8	3.3	18.3	9.2	23.7
3-Opal Seal	15.7±3.9	4.0	17.2	9.9	21.2

*Via analysis of variance and a post hoc Tukey HSD test, Group 1 was significantly greater (p<0.05) from Group 3, but Groups 2 and 3 were not significantly different (p>0.05) from each other.

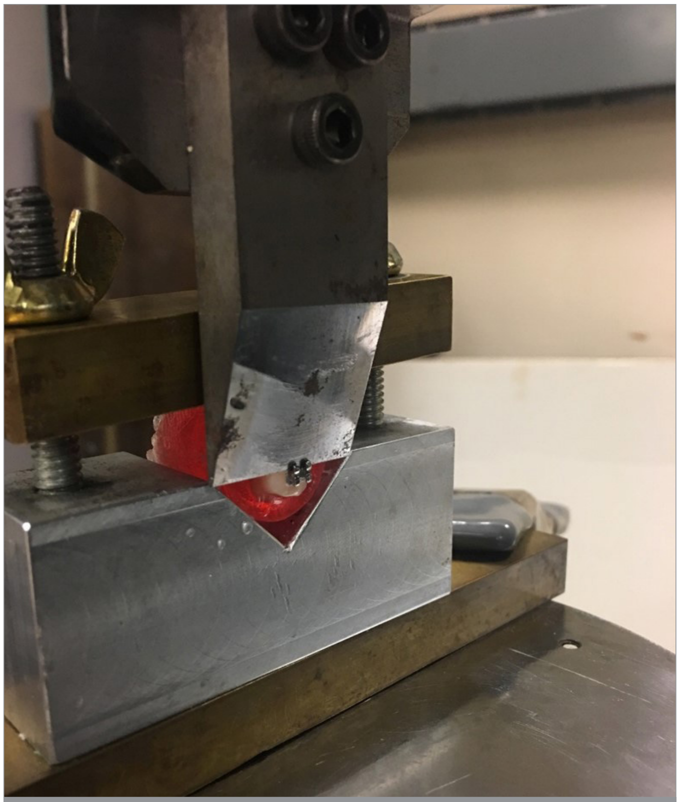

Figure 1. Shear bond strength test

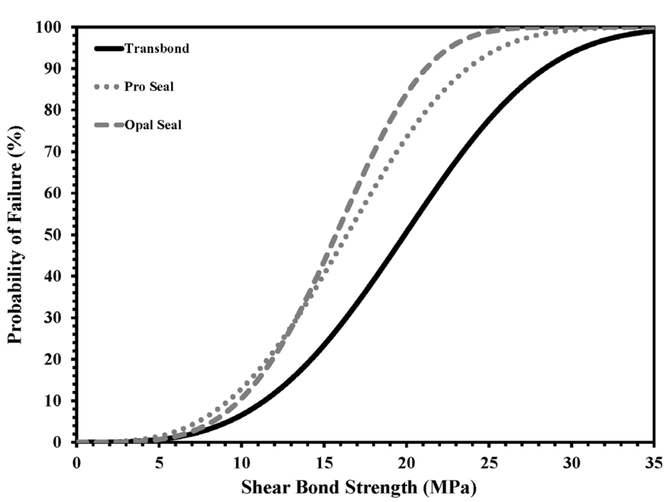

Figure 2. Weibull curves for the shear bond strength of the three groups

Table 2. Comparison of Adhesive remnant index (ARI) scores among groups by Kruskal-Wallis and Mann-Whitney U tests.

	ARI scores*			
Group	0	1	2	3
1-Transbond	0	10	10	0
2-Pro Seal	0	9	11	0
3-Opal Seal	0	0	20	0

*There was no significant difference (p>0.05) between Groups 1 and 2; however, Group 3 was significantly different (p=0.001) from Groups 1 and 2.

at a crosshead speed of 0.5 mm/min was used to debond each bracket. The force was measured in Newtons and converted to MPa by dividing by the bracket base area.

After each bracket was debonded, the enamel surface and bracket were examined using an optical microscope and scored using the adhesive remnant index (ARI) (20). The ARI score represents the amount of adhesive remaining on the enamel after debonding the bracket. There are 4 possible ARI scores: 0=no adhesive left on the tooth, 1=less than 50% of the adhesive left on the tooth, 2=more than 50% of the adhesive left on the tooth, and 3=all of the adhesive left on the tooth.

SBS was analyzed using one-way analysis of variance and a post hoc Tukey HSD test at $p \leq 0.05$ level of significance. ARI data were compared using Kruskal-Wallis and Mann-Whitney U tests via the Statistical Package for Social Sciences version 23.0 software (IBM Corp.; Armonk, NY, USA).

RESULTS

The SBSs (MPa) of the groups are listed in Table 1. The SBS for Transbond XT Primer, was significantly greater than that for Opal Seal sealant (p<0.05), but Pro Seal and Opal Seal sealants were not significantly different from each other (p<0.05). Weibull analysis also indicated that the Transbond XT Primer group displayed greater bond strengths. However, Opal Seal possessed the greatest Weibull modulus, indicating slightly greater reliability between the groups as it had less broadly distributed bond strength values. This is further reflected in the lower standard deviation for the Opal Seal group. Figure 2 displays Weibull curves plotting "Probability of Failure" versus Shear Bond Strength that are consistent with Table 1. In terms of bond failure site, the Opal Seal group had significantly greater ARI scores (p=0.001; Table 2), indicating that more adhesive remained on the tooth after bond strength testing.

DISCUSSION

The purpose of this study was to determine if there was a difference in SBS between Pro Seal and Opal Seal sealants. Previous studies have shown that Pro Seal sealant exhibited clinically acceptable bond strength and compared different properties of Pro Seal and Opal Seal sealants (3, 7, 9, 10). The literature shows that there is an added benefit to using a sealant in the protection against the formation of white spot lesions. Specifically, Tasios et al. (21) conducted a meta-analysis to assess the efficacy of preventive interventions against the development of white spot lesions and found that sealants, active patient reminders, and fluoride varnishes were associated with reduced white spot lesion incidence. Five randomized clinical trials were included in their analysis that supported the use of sealants. However, there has not been a study that has compared the bond strength of Opal Seal sealant to Pro Seal sealant.

Results showed that the two orthodontic sealants performed similarly with respect to SBS; thus, the null hypothesis was accepted, although the adhesive primer (control) group had a statistically greater SBS than Opal Seal sealant group. Transbond XT Adhesive with Transbond XT Primer has been regarded as the gold standard when bonding to enamel (22). Nevertheless, both Pro Seal and Opal Seal sealants had SBS over 15 MPa, which is considered clinically acceptable according to Tavas and Watts who stated that bond strength of 6 kgf was needed in 24 hours (23). For comparison, the average SBS of Opal Seal at 15.7 MPa corresponds to 16 kgf (15.7 MPa×10 mm^2/9.8 m/s^2). Comparatively, the force levels for debonding the brackets in this study using Transbond XT Primer and Pro Seal sealant were slightly higher than those reported by Lowder et al. (9). In the study by Lowder et al. (9), the specimens were stored for 30 days and thermocycled, both of which are factors that have been shown to decrease the bond strength (24-26). Furthermore, the crosshead speed was slower in this study, although the effect of crosshead speed on orthodontic bond strength has been inconsistent (27-29).

ARI is one of the most commonly used methods to determine the quality of adhesion at the bracket/adhesive and tooth/adhesive interfaces. The ARI results for the Transbond XT Primer and Pro Seal sealant groups were quite evenly split between ARI 1 and 2 scores, whereas Opal Seal sealant had a significantly greater ARI score, indicating that more amount of adhesive consistently remained on the teeth after debonding. Although the exact composition and concentration of all monomers in the products are proprietary, the Safety Data Sheets list Opal Seal sealant and Transbond XT Adhesive as containing bisphenol A-glycidyl methacrylate, whereas Pro Seal sealant does not contain the same product. Opal Seal sealant and Transbond XT Adhesive may have better compatibility, thereby forming a stronger bond and shifting the weak link onto the bracket/adhesive interface than the other two groups. However, more research is needed to confirm this. While more adhesive left on the tooth may lower the risk of enamel fracture, it would also increase the clean-up time by the orthodontist. This study used standard stainless steel brackets that required application of adhesive to the bracket base; use of a different bracket system may alter the adhesive failure site. For instance, a recent study found that precoated brackets had lower ARI scores than the conventional brackets (30). This can be attributed to the fact that precoated brackets have a premeasured uniform layer of adhesive. Alternatively, the lower ARI scores may also be the result of the more uniform pressure that is applied in placing the adhesive on the bracket mesh during manufacturing, allowing for better penetration of the mesh (30). Failures at the bracket/adhesive interface may also be caused by the incomplete polymerization of the adhesive owing to lack of light curing behind the bracket.

Orthodontic literature outlines different factors that influence bond strength and ARI (24). Those factors include operator technique, patient behavior, enamel variations, specimen storage time, enamel conditioning procedures, type of adhesive, and bracket base area/design (24). In this study, all the materials and processes were the same except for the primer/sealants being compared. Protocols from the study by Fox et al. (31) were used to help with standardization of this study. As this was an *in vitro* study, there were limitations to translating the current research to clinical practice. Thermocycling is frequently performed in orthodontic bonding studies to serve as an artificial aging mechanism to gain insight on long-term bond strength. Thermocycling has been found to decrease the orthodontic bond strength in a majority of studies, but it is not always observed (26, 32-35, 36-38). Nevertheless, the SBS values reported in this study were at 48 hours after bonding without thermocycling; thus, the results do not represent longer conditions that may be of greater interest. Furthermore, the upper and lower premolars were used in this study without stratification. Generalization to other teeth is problematic because enamel shape and tooth type influence the bond strength (39, 40-42); however, two of these studies found no difference in bond strength between upper and lower premolars (40, 41) in contrast to the study by Ozturk et al. (42). Therefore, a clinical comparison of the two sealants is necessary to properly ascertain their demineralization efficacy and bonding durability.

CONCLUSION

Opal Seal and Pro Seal sealants have similar SBS but generally exhibit lower bond strengths than adhesive primer. Opal Seal sealant leaves more adhesive on the tooth when debonding occurs, which could lead to an increase in debond appointment time.

Ethics Committee Approval: This study was approved by the Institutional Review Board of Marquette University (Approval No: DT-027).

Informed Consent: Written informed consent was obtained from the patients who agreed to donate their extracted teeth for research purposes.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – A.O., D.B.; Design – J.K., A.O., D.B.; Resources – J.K., D.B.; Materials – J.K., D.B.; Data Collection and/or Processing – J.K., D.C., D.B.; Analysis and/or Interpretation – J.K. D.B.; Literature Search – J.K., D.B.; Writing Manuscript – J.K., D.B.; Critical Review – D.C., A.O.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Sundararaj D, Venkatachalapathy S, Tandon A, Pereira A. Critical evaluation of incidence and prevalence of white spot lesions during fixed orthodontic appliance treatment: A meta-analysis. J Int Soc Prev Community Dent 2015; 5: 433-9. [Crossref]
2. Oz AZ, Oz AA, Yazıcıoglu S. In vivo effect of antibacterial and fluoride-releasing adhesives on enamel demineralization around brackets: A micro-CT study. Angle Orthod 2017; 87: 841-6. [Crossref]
3. Premaraj TS, Rohani N, Covey D, Premaraj S, Hua Y, Watanabe H. An in-vitro evaluation of mechanical and esthetic properties of orthodontic sealants. Eur J Dent 2014; 8: 487-92. [Crossref]
4. Behnan SM, Arruda AO, González-Cabezas C, Sohn W, Peters MC. In-vitro evaluation of various treatments to prevent demineralization next to orthodontic brackets. Am J Orthod Dentofacial Orthop 2010; 138: 712.e1-7; discussion 712-3. [Crossref]
5. Hu W, Featherstone JD. Prevention of enamel demineralization: An in-vitro study using light-cured filled sealant. Am J Orthod Dentofacial Orthop 2005; 128: 592-600. [Crossref]
6. Buren JL, Staley RN, Wefel J, Qian F. Inhibition of enamel demineralization by an enamel sealant, Pro Seal: An in-vitro study. Am J Orthod Dentofacial Orthop 2008; 133(4 Suppl): 88-94. [Crossref]
7. Maxfield BJ, Hamdan AM, Tüfekçi E, Shroff B, Best AM, Lindauer SJ. Development of white spot lesions during orthodontic treatment: perceptions of patients, parents, orthodontists, and general dentists. Am J Orthod Dentofacial Orthop 2012; 141: 337-44. [Crossref]
8. Bishara SE, Oonsombat C, Soliman MM, Warren J. Effects of using a new protective sealant on the bond strength of orthodontic brackets. Angle Orthod 2005; 75: 243-6.
9. Lowder PD, Foley T, Banting DW. Bond strength of 4 orthodontic adhesives used with a caries-protective resin sealant. Am J Orthod Dentofacial Orthop 2008; 134: 291-5. [Crossref]
10. Premaraj TS, Rohani N, Covey D, Premaraj S. In vitro evaluation of surface properties of Pro Seal® and Opal® SealTM in preventing white spot lesions. Orthod Craniofac Res 2017; 20: 134-8. [Crossref]
11. Hadler-Olsen S, Sandvik K, El-Agroudi MA, Øgaard B. The incidence of caries and white spot lesions in orthodontically treated adolescents with a comprehensive caries prophylactic regimen--a prospective study. Eur J Orthod 2012; 34: 633-9. [Crossref]
12. Product Catalog. Reliance Orthodontic Products, Inc. 2020.
13. Opal Seal Primer and Sealer IFU. Ultradent Products, Inc. 2017.
14. Bartels AA, Evans CA, Viana G, Bedran-Russo AK. Demineralization of resin-sealed enamel by soft drinks in a clinically relevant pH cycling model. Am J Dent 2016; 29: 115-9.
15. Tarvade SM, Deshmukh AA, Daokar SG. Evaluation of Bond Strength: An In vitro Study using Pro Seal. J Int Oral Health 2014; 6: 1-3.
16. Paschos E, Okuka S, Ilie N, Huth KC, Kickel R, Rudzki-Janson I. Investigation of shear-peel bond strength of orthodontic brackets on enamel after using Pro Seal. J Orofac Orthop 2006; 67: 196-206. [Crossref]
17. El Bokle D, Munir H. An in vitro study of the effect of Pro Seal varnish on the shear bond strength of orthodontic brackets. World J Orthod 2008; 9: 141-6.
18. Phan X, Akyalcin S, Wiltshire WA, Rody WJ Jr. Effect of tooth bleaching on shear bond strength of a fluoride-releasing sealant. Angle Orthod 2012; 82: 546-51. [Crossref]
19. Seeliger JH, Botzenhart UU, Gedrange T, Kozak K, Stepien L, Machoy M. Enamel shear bond strength of different primers combined with an orthodontic adhesive paste. Biomed Tech (Berl) 2017; 62: 415-20. [Crossref]
20. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod 1984; 85: 333-40. [Crossref]
21. Tasios T, Papageorgiou SN, Papadopoulos MA, Tsapas A, Haidich AB. Prevention of orthodontic enamel demineralization: A systematic review with meta-analyses. Orthod Craniofac Res 2019; 22: 225-35. [Crossref]
22. Hellak A, Ebeling J, Schauseil M, Stein S, Roggendorf M, Korbmacher-Steiner H. Shear bond strength of three orthodontic bonding systems on enamel and restorative materials. Biomed Res Int 2016; 2016: 6307107. [Crossref]
23. Tavas MA, Watts DC. A visible light-activated direct bonding material: An in vitro comparative study. Br J Orthod 1984; 11: 33-7. [Crossref]
24. Murray SD, Hobson RS. Comparison of in vivo and in vitro shear bond strength. Am J Orthod Dentofacial Orthop 2003; 123: 2-9. [Crossref]
25. Oesterle LJ, Shellhart WC. Effect of aging on the shear bond strength of orthodontic brackets. Am J Orthod Dentofacial Orthop 2008; 133: 716-20. [Crossref]
26. Sokucu O, Siso SH, Ozturk F, Nalcaci R. Shear bond strength of orthodontic brackets cured with different light sources under thermocycling. Eur J Dent 2010; 4: 257-62. [Crossref]
27. Bishara SE, Soliman M, Laffoon J, Warren JJ. Effect of changing a test parameter on the shear bond strength of orthodontic brackets. Angle Orthod 2005; 75: 832-5.
28. Klocke A, Kahl-Nieke B. Influence of cross-head speed in orthodontic bond strength testing. Dent Mater 2005; 21: 139-44. [Crossref]
29. Shooter KJ, Griffin MP, Kerr B. The effect of changing crosshead speed on the shear bond strength of orthodontic bonding adhesive. Aust Orthod J 2012; 28: 44-50.
30. Guzman UA, Jerrold L, Vig PS, Abdelkarim A. Comparison of shear bond strength and adhesive remnant index between precoated and conventionally bonded orthodontic brackets. Prog Orthod 2013; 14: 39. [Crossref]
31. Fox NA, McCabe JF, Buckley JG. A critique of bond strength testing in orthodontics. Br J Orthod 1994; 21: 33-43. [Crossref]
32. Arici S, Arici N. Effects of thermocycling on the bond strength of a resin-modified glass ionomer cement: an in vitro comparative study. Angle Orthod 2003; 73: 692-6.
33. Bishara SE, Ajlouni R, Laffoon JF. Effect of thermocycling on the shear bond strength of a cyanoacrylate orthodontic adhesive. Am J Orthod Dentofacial Orthop 2003; 123: 21-4. [Crossref]
34. Lopes GV, Correr-Sobrinho L, Correr AB, Godoi APT, Vedovello SAS, Menezes CC. Light activation and thermocycling methods on the shear bond strength of brackets bonded to porcelain surfaces. Braz Dent J 2020; 31: 52-6. [Crossref]
35. Turk T, Elekdag-Turk S, Isci D, Cakmak F, Ozkalayci N. Shear bond strength of a self-etching primer after 10,000 and 20,000 thermal cycles. J Adhes Dent 2010; 12: 117-22.
36. Costa AR, Correr AB, Puppin-Rontani RM, Vedovello SA, Valdrighi HC, Correr-Sobrinho L, et al. Effects of thermocycling and light source on the bond strength of metallic brackets to bovine teeth. Braz Dent J 2011; 22: 486-9. [Crossref]
37. Yuasa T, Iijima M, Ito S, Muguruma T, Saito T, Mizoguchi I. Effects of long-term storage and thermocycling on bond strength of two self-etching primer adhesive systems. Eur J Orthod 2010; 32: 285-90. [Crossref]

38. Cerekja E, Cakirer B. Effect of short curing times with a high-intensity light-emitting diode or high-power halogen on shear bond strength of metal brackets before and after thermocycling. Angle Orthod 2011; 81: 510-6. [Crossref]
39. Hioki M, Shin-Ya A, Nakahara R, Vallittu PK, Nakasone Y, Shin-Ya A. Shear bond strength and FEM of a resin-modified glass ionomer cement--effects of tooth enamel shape and orthodontic bracket base configuration. Dent Mater J 2007; 26: 700-7. [Crossref]
40. Hobson RS, McCabe JF, Hogg SD. Bond strength to surface enamel for different tooth types. Dent Mater 2001; 17: 184-9. [Crossref]
41. Linklater RA, Gordon PH. An ex vivo study to investigate bond strengths of different tooth types. J Orthod 2001; 28: 59-65. [Crossref]
42. Oztürk B, Malkoç S, Koyutürk AE, Catalbas B, Ozer F. Influence of different tooth types on the bond strength of two orthodontic adhesive systems. Eur J Orthod 2008; 30: 407-12. [Crossref]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.20017

Original Article

Cephalometric Evaluation of Anterior Cranial Base Slope in Patients with Skeletal Class I Malocclusion with Low or High SNA and SNB Angles

Hasan Camcı, Farhad Salmanpour

Department of Orthodontics, Afyonkarahisar Health Science University, Afyonkarahisar, Turkey

Cite this article as: Camcı H, Salmanpour F. Cephalometric Evaluation of Anterior Cranial Base Slope in Patients with Skeletal Class I Malocclusion with Low or High SNA and SNB Angles. Turk J Orthod 2020; 33(3): 171-6.

Main points:

- The SN plane, anterior cranial base inclination (ACB), is frequently used by orthodontists as a reference plane.
- In our study, the relationship between low or high SNA, SNB and ACB was evaluated in patients with skeletal Class I malocclusion.
- According to the findings, high values of SNA and SNB were caused by flatter ACB and the low SNA and SNB values were the result of the steeper ACB slope.

ABSTRACT

Objective: In the cephalometric analyses, it is observed that both SNA and SNB angles are higher or lower than normal for some skeletal Class I patients. The aim of this study was to assess the correlation between low or high SNA, SNB angles, and anterior cranial base (ACB) slope.

Methods: One hundred and seventeen skeletal Class I patients (45 males with a mean age of 14.5 years, 72 females with a mean age of 14.4 years) were evaluated in three groups. Group 1(n=40): Control group, individuals with normal SNA(82°±2°), and SNB(80°±2°) values. Group 2 (n=37): Patients with SNA>84° and SNB >82°, Group 3 (n=40): Patients with both SNA and SNB values lower than 78°. On the cephalometric radiographs, three angulars (SN / FH; anterior cranial base, Ba-S / FH; posterior cranial base, SN-Ba; total cranial base) and seven linear (S-FH, N-FH, Δ, Ba-S, Ba-N, Ba-A, Ba-B) measurements were performed to analyze the vertical and horizontal positions of the S and N points and thereby the ACB slope. One-way ANOVA and Kruskal Wallis tests were used for statistical analysis.

Results: The ACB slope was observed to be relatively flatter in Group 2, and steeper in Group 3 ($p<0.05$). The location of the S and N points in the sagittal plane did not significantly affect the SNA and SNB. However, the vertical position of the S and N points was a factor determining the inclination of the ACB, therefore the SNA and SNB.

Conclusion: ACB slope directly affected SNA and SNB measurements. ACB might lead to misleading results when used as a reference plane.

Keywords: Cephalometric analysis, cranial base, skeletal Class I malocclusion

INTRODUCTION

Cephalometric analysis has been a decisive factor in orthodontic treatment planning for years (1). During the analyses, numerous measurements are performed on dentofacial structures using certain reference planes (2, 3). One of these planes used as a reference in the measurements is the anterior cranial base (Sella-Nasion) (4). The anterior cranial base (ACB) might be affected by both the direction and degree of the growth of the craniofacial structures. Several studies have shown that its angular slope or length enhances the development of sagittal or vertical skeletal malocclusions (5). The degree of its slope could also vary depending on the race or area in which the research was carried out (6, 7). Nevertheless, ACB is still considered as relatively stable throughout craniofacial growth compared with other reference planes (8). Therefore, ACB is generally preferred for superimposing initial and final cephalometric radiographs (9).

Address for Correspondence: Hasan Camcı, Department of Orthodontics, Afyonkarahisar Health Science University, Afyonkarahisar, Turkey
E-mail: dt.hasan@hotmail.com

Received: February 13, 2020
Accepted: July 21, 2020
Available Online Date: August 18, 2020

The literature involves numerous studies investigating the relationship between cranial base slope and skeletal malocclusions. According to some of these reports, the cranial base inclination affects the formation or severity of the malocclusion (10, 11). However, the cranial slope has not been identified as a factor in other studies (12, 13). The slope, length, and stability of ACB are critical to accurately predict complex growth mechanisms of craniofacial structures. Renfroe (14), Bjork (15), and Ricketts (16) emphasized the importance of this reference plane.

ACB is commonly used for superimposition of cephalometric radiographs. Because the growth of ACB is completed earlier than other craniofacial structures and is highly stable in the first decade of life (17). Throughout intrauterine life, the cranial base slope is almost flat. However, as the brain grows exponentially, the slope increasingly becomes steeper (18). In the first 5 years of life, ACB shows rapid development and completes its growth by 90% (19, 20). During growth, the cranial base, moving forward and downward, determines maxillary and mandibular growth and development pattern.

Sometimes in initial cephalometric measurements, both SNA and SNB are seen to be low (SNA, SNB <78°) or to be high (SNA>84° and SNB >82°) and this is not an uncommon circumstance. These patients, however, have good facial esthetics and occlusal relations, and neither bimaxillary retrusion nor bimaxillary protrusion is seen in the extraoral examination of these patients. In this scenario, what are the factors that caused this situation? This study was based on the null hypothesis that there is no correlation between high or low SNA and SNB values and ACB slope and length.

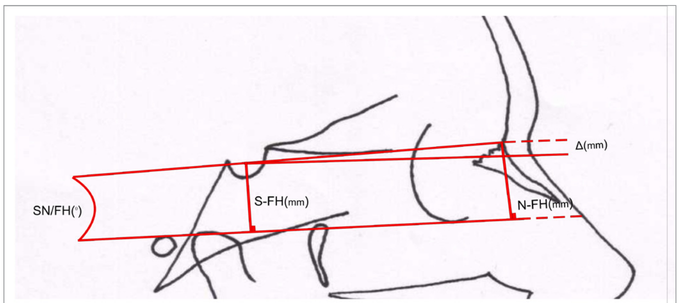

Figure 1. Vertical assessment of S and N points. ACB slope calculation with SN / FH angle

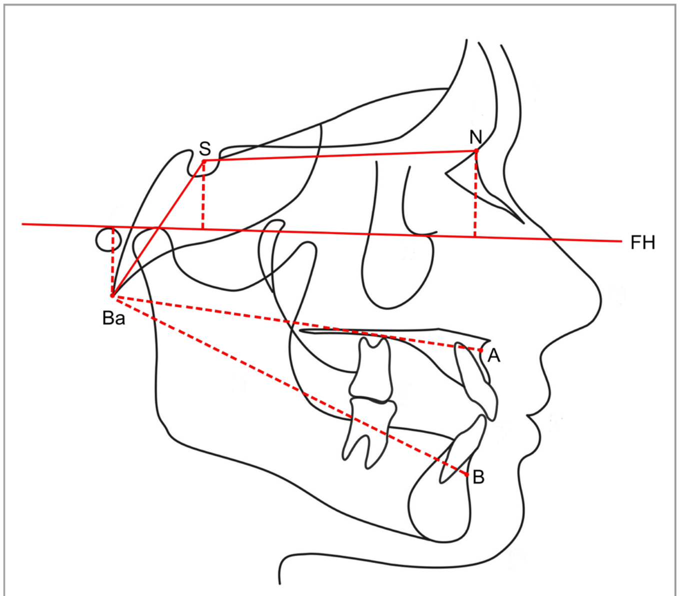

Figure 2. Horizontal assessment of S, N, A and B points

METHODS

The experimental protocols of this retrospective study were approved (02.08.2019-253) by Afyonkarahisar Health Sciences University Clinical Research Ethics Committee. Written informed consent forms were obtained from all the patients included in the study. The study was conducted on lateral cephalometric films of the patients who applied to orthodontic department of Afyonkarahisar Health Sciences University. All cephalometric radiographs were taken as routinely performed in the natural head position. In the power analysis to determine sample size, it was revealed that at least 37 patients were required for each group in order to obtain sufficient statistical power (n>37, α=0.05, and 1-β=0.80). One hundred and seventeen skeletal Class I patients (45 males with a mean age of 14.5 years, 72 females with a mean age of 14.4 years) were included in the study. The following criterias of the patient selection were considered:

- High quality cephalometric radiographs for easy identification of the anatomical landmarks
- Healthy patients without systemic diseases, congenital deformities or significant facial asymmetry
- No history of previous orthodontic treatment

The selected patients were divided into three groups based on the following criterias. The definitions of the groups were as follows: Group 1 (n=40): Control group, individuals with normal SNA (82°±2°) and SNB (80°±2°) values. Group 2 (n=37): Patients with SNA>84° and SNB>82°, Group 3 (n=40): Patients with both SNA and SNB values lower than 78°. The following measurements were performed on the lateral cephalometric radiographs routinely used for diagnostic purposes (21, 22) (Figure 1 and 2):

- SNA: Angle formed by the intersection of sella-nasion and nasion- A lines
- SNB: Angle formed by the intersection of sella-nasion and nasion- B lines
- ANB: Angle formed by the intersection of nasion- A and nasion- B lines
- SN / FH: Angle between anterior cranial base and Frankfort horizontal plane
- SN-Ba angle: Total cranial base angle
- Ba-S / FH: Angle between posterior cranial base and Frankfort horizontal plane
- S-FH length: Perpendicular distance from Sella to the Frankfort horizontal plane
- N-FH length: Perpendicular distance from Nasion to the Frankfort horizontal plane
- Delta (Δ): Difference between the N-FH and S-FH
- Ba-S length: Distance between Ba and S projected on FH plane
- Ba-N length: Distance between Ba and N projected on FH plane
- Ba-A length: Horizontal distance between Basion and A
- Ba-B length: Horizontal distance between Basion and B

Table 1. Intra-class correlation coefficients (ICCs) testing inter-observer reliability

Measurements	SNA	SNB	SN/FH	SN-Ba	S-FH	N-FH	Δ	Ba-A	Ba-B
Correlation coefficient	0.950	0.974	0.923	0.970	0.958	0.946	0.921	0.985	0.990

S: Sella; N: Nasion; FH: Frankfurt horizontal; Δ: Delta; Ba: Basion

Table 2. Comparison of the measurements with one-way ANOVA test and Kruskal Wallis test between the groups

		N	Mean±SD	p
SN/FH(°)	Group 1	40	7.52±2.57	0.000***
	Group 2	37	5.03±2.56	
	Group 3	40	11.88±3.31	
SN-Ba(mm)	Group 1	40	125.59±4.43	0.000***
	Group 2	37	123.40±4.64	
	Group 3	40	132.26±4.19	
Ba-S/FH(°)	Group 1	40	118.04±4.19	0.064
	Group 2	37	118.52±4.95	
	Group 3	40	120.36±4.66	
S-FH(mm)	Group 1	40	18.98±2.64	0.000***
	Group 2	37	19.47±2.41	
	Group 3	40	16.18±2.34	
N-FH(mm)	Group 1	40	27.26±2.55	0.000***
	Group 2	37	24.98±3.36	
	Group 3	40	29.27±3.18	
Δ (mm)	Group 1	40	8.29±2.70	0.000***
	Group 2	37	5.66±2.91	
	Group 3	40	13.08±3.50	
Ba-S(mm)	Group 1	40	20.78±3.20	0.887
	Group 2	37	21.02±3.17	
	Group 3	40	21.10±2.85	
Ba-A(mm)	Group 1	40	83.42±5.61	0.007**
	Group 2	37	86.92±5.38	
	Group 3	40	82.73±4.13	
Ba-B(mm)	Group 1	40	80.08±5.72	Ψ0.000***
	Group 2	37	84.50±6.72	
	Group 3	40	77.84±4.66	
Ba-N(mm)	Group 1	40	83.83±6.10	Ψ0.661
	Group 2	37	84.94±5.12	
	Group 3	40	84.23±4.91	

S: Sella; N: Nasion; FH: Frankfurt horizontal; Ba: Basion; Δ: Delta; ANOVA: Analysis of variance
Ψ: p values for Kruskal Wallis test
p values for one way ANOVA test; ** p<0.01, ***p<0.001

Table 3. Results of Tukey multiple comparison tests of the normally distributed variables

Dependent Variable	Group 1/ Group 2	Group 2/ Group 3	Group 1/ Group3
SN/FH(°)	0.001**	0.000***	0.000***
SN-Ba(mm)	0.081	0.000***	0.000***
Ba-S/FH(°)	0.893	0.067	0.190
S-FH(mm)	0.664	0.000***	0.000***
N-FH(mm)	0.004**	0.000***	0.011*
Δ (mm)	0.001**	0.000***	0.000***
Ba-S(mm)	0.936	0.993	0.885
Ba-A(mm)	0.009**	0.001**	0.813

S: Sella; N: Nasion; FH: Frankfort horizontal; Δ: Delta; Ba: Basion; *p<0.05, ** p<0.01, ***p<0.001

Table 4. Results of Tamhane test of the non-normally distributed variables

Dependent Variable	Group 1/ Group 2	Group 2/ Group 3	Group 1/ Group3
Ba-N(mm)	0.770	0.899	0.984
Ba-B(mm)	0.008**	0.000***	0.169

Ba: Basion; ** p<0.01, ***p<0.001

All measurements were performed by a single experienced researcher for the reliability of the study (F.S.). AudaxCeph Version 5.X software (Ljubljana, Slovenya) was used for the cephalometric measurements.

Statistical Analysis

The Statistical Package for Social Sciences version 22.0 software (IBM Corp.; Armonk, NY, USA) was used to calculate the mean values and standard deviations of each parameter. One-way ANOVA test and post hoc Tukey test were performed to compare homogeneous datas among groups. Analysis of non-homogeneous datas (Ba-N and Ba-B) were conducted with Kruskal-Wallis and the post hoc Tamhane test.

Error of the Method

In ten randomly selected patients, all parameters were remeasured one month later by the same researcher (F.S.). The initial and repeated measurements were compared using the intra-class correlation coefficients (ICCs) test to ensure the inter-observer reliability (Table 1).

RESULTS

The descriptive statistics, the comparisons among groups by one way ANOVA and Kruskal Wallis tests, and the results of post hoc Tukey and Tamhane tests were given in Table 2, Table 3 and Table 4. Ba-S measurements showed that there was no statistically significant difference between the groups in terms of the anteroposterior position of the S point (p>0.05). In other words, sagittal location of the S point had no effect on the ACB slope.

The S point in Group 3 was positioned more inferiorly than the other two groups according to S-FH measurements. The only statistically significant difference was observed between Group 3 and the other two groups (p<0.01).

The N point was at the highest position in Group 3 and the lowest position in Group 1 according to N-FH values. This measurement showed significant difference between the groups (p<0.01). In the Ba-S measurements, the sagittal position of the N point did not show any statistically significant difference between groups (p>0.05) (Figure 3).

The length of Delta (Δ) indicating the vertical distance between S and N points was the highest in Group 3 and the lowest in Group 2. This finding suggested that the slope of the anterior cranial base was steeper in Group 3 and flatter in Group 2.

In Group 2, points A and B were located more anteriorly than the other two groups, according to the measurements of Ba-A and Ba-B. This revealed that the high value of both the SNA and the SNB was caused not only by the relatively flat S-N plane but also by the more anterior location of the A and B points.

The highest values for the SN / FH findings were found in Group 3 and the lowest in Group 2. This variation between the groups was statistically significant (p<0.01). The SN-Ba angle of Group 3 was significantly higher than other two groups (p<0.01).

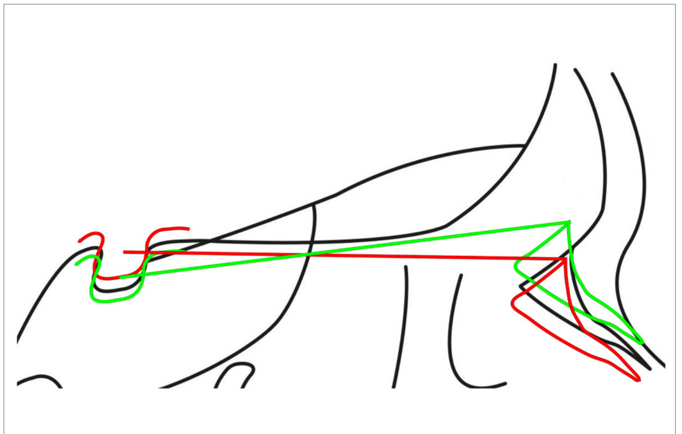

Figure 3. Schematic illustration of ACB slopes of the groups. Black: Control group, Green: Group 2, Red: Group 3

DISCUSSION

The primary prerequisite for effective orthodontic treatment is an accurate description and diagnosis of the malocclusions. However, the reference planes used in the diagnosis of the malocclusions may sometimes provide misleading results. The cranial base inclination or anatomical variations of other reference planes might play a role in the type and severity of the malocclusions (23). Previous researchers investigating the relationship between cranial base and malocclusion have generally assessed lengths and angles of the anterior and posterior cranial base (24). In addition to the length and angle of the cranial base, the vertical and sagittal locations of the S and N points were evaluated in our study. Sella represents the posterior part of the cranial base and Nasion represents the upper part of the middle face. Besides the vertical and horizontal position of the nasion, the slope of the ACB could alter the SNA and SNB angles considerably. For instance, two people with almost identical facial prognathism in their natural head position may display a significant difference in the slope of the SN plane (25). This causes confusion over the reliability of intracranial reference planes.

Numerous studies have investigated the accuracy and reliability of SN and FH planes (26,27). SN plane largely completes its development in the first decades of life. Throughout the development of craniofacial structures, S and N points relocate (8). Particularly the migration of point N migration continues parallel to the facial development for many years. In the same way, the development of craniofacial structures affects the FH plane. The FH plane was used as a reference for determining the degree of inclination of the SN plane and the vertical position of the S and N points. The reasons for selecting FH were because it is located close to the anterior cranial base and very small relocation in semi-circular ear canals and lower border of orbita occur during the early ages of life (28-31).

However, FH also has some disadvantages: its accuracy and reproducibility rely on the natural head position, difficulty in identification of the right and left orbita or meatus acusticus exter-

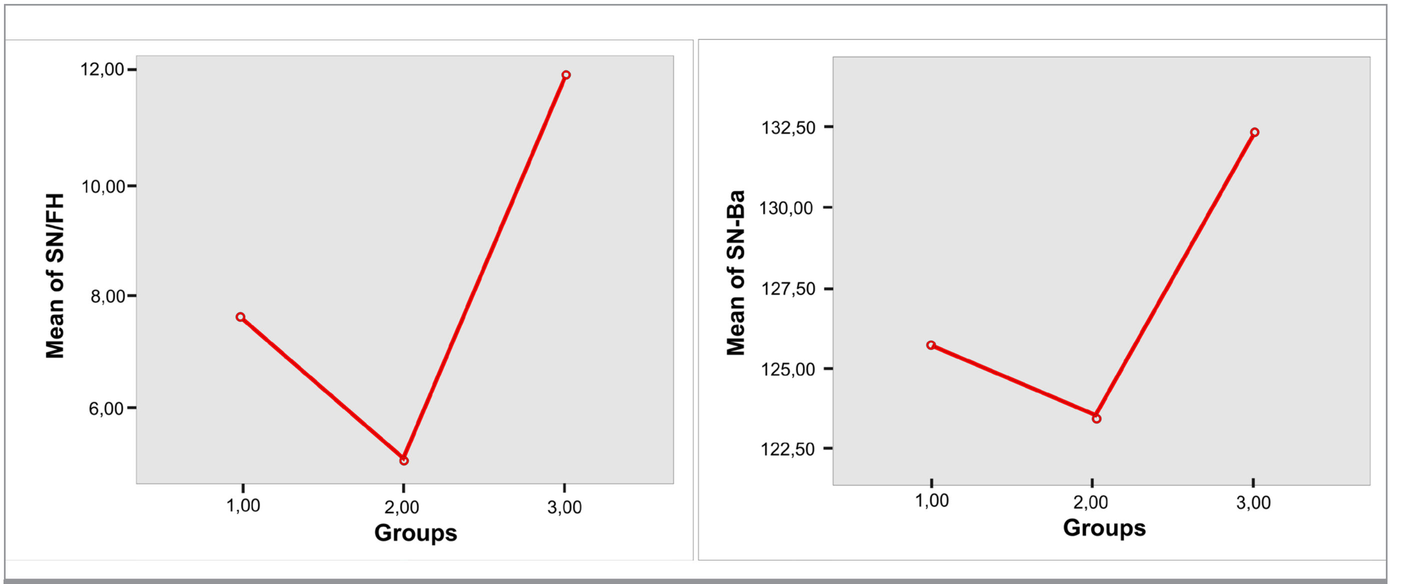

Figure 4. The diagrams showing SN / FH and SN-Ba values distribution between the groups

nus, and the presence of contradictory findings in the literature on the variation of this plane.

Since Basion was used as a reference, the measurements of S and N points in the sagittal direction may have been affected. Because the position of Basion could differ horizontally and vertically, depending on the growth and development of the cranium. However, Pelo et al. (32) have reported that the use of Ba as a reference point provides reliable results.

The anteroposterior or up-down tipping of the posterior (Ba-S) and anterior base (S-N) has an impact on the cranial base angle (SN-Ba) (20). The steep posterior base causes the lower jaw to displace anteriorly and changes the position of the B point. The increased SN-Ba angle leads to a posterior localization of the mandible. In the literature, several researchers reported a correlation between cranial base angle and skeletal malocclusions (11, 33). However, contradictory findings have also been stated (34, 35). An explanation for inconsistent findings is that not only the cranial base inclination or angle but several variables are involved in the development of malocclusions (36). Therefore, only skeletal Class I patients were included in our research to eliminate malocclusion-related factors. However, in this retrospective study, other factors could not be eliminated. In addition, patient selection without age and sex consideration was another limitation of this study. The variations in the age and sex of subjects were a factor affecting the results. Because the morphological maturation of the human skull differs among men and women in terms of duration and its final size (17).

The mean SN / FH angle value was reported at 7^0, and remains relatively stable throughout the growth (37). Our findings in SN / FH measurements were close to normative values for Groups 1 and 2, but this value was higher in Group 3. Graphical distributions of SN / FH and SN-Ba angle measurements among groups were identical (Figure 4). This finding allows claiming that the common variable of both angles, namely SN, was the primary factor determining the two measurements. It also revealed that the FH plane and the Ba point used as a reference had no negative impact on the measurements.

Although the ACB is known as a stable plane, it should be noted that its slope may affect cephalometric measurements. Since the vertical or horizontal positions of the S and N points vary depending on age and gender, further longitudinal studies are needed with larger and more specific sample groups.

CONCLUSION

Lower position of the point N, more forward position of the point A and B were responsible for the increased SNA and SNB. High SNA-SNB Group data (S-FH, Ba-S) were not affected by the sagittal and vertical displacement of the S point. Also, the position of the N point in the sagittal plane did not affect SNA and SNB. In addition, the slope of ACB was flatter in this group.

Low SNA and SNB values were due to the more inferior localization of the S point. Another reason was the superior location of the N point. In low SNA-SNB Group, the sagittal position of the points S and N did not affect the SNA and SNB. The slope of ACB was steeper.

Our null hypothesis was rejected. ACB slope affected SNA and SNB measurements.

Ethics Committee Approval: This study was approved by Ethics committee of Afyonkarahisar Health Sciences University (Approval No: 02.08.2019-253).

Informed Consent: Written informed consent forms were obtained from all the patients included in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – H.C.; Design – H.C., F.S.; Supervision – H.C.; Resources – H.C.; Materials – H.C.; Data Collection and/or Processing – H.C., F.S.; Analysis and/or Interpretation – H.C., F.S.; Literature Search – H.C.; Writing Manuscript – H.C.; Critical Review – H.C., F.S.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Durão AR, Alqerban A, Ferreira AP, Jacobs R. Influence of lateral cephalometric radiography in orthodontic diagnosis and treatment planning. Angle Orthod 2015; 85: 206-10. [Crossref]
2. Wu J, Hägg U, Rabie ABM. Chinese norms of McNamara's cephalometric analysis. Angle Orthod 2007; 77: 12-20. [Crossref]
3. Sharma JN. Steiner's cephalometric norms for the Nepalese population. J Orthod 2011; 38: 21-31. [Crossref]
4. Madsen DP, Sampson WJ, Townsend GC. Craniofacial reference plane variation and natural head position. Eur J Orthod 2008; 30: 532-40. [Crossref]
5. Sanggarnjanavanich S, Sekiya T, Nomura Y, Nakayama T, Hanada N, Nakamura Y. Cranial-base morphology in adults with skeletal Class III malocclusion. Am J Orthod Dentofac Orthop 2014; 146: 82-91. [Crossref]
6. Ajayi EO. Cephalometric norms of Nigerian children. Am J Orthod Dentofac Orthop 2005; 128: 653-656. [Crossref]
7. Alves PVM, Mazuchelli J, Patel PK, Bolognese AM. Cranial base angulation in Brazilian patients seeking orthodontic treatment. J Craniofac Surg 2008; 19: 334-8. [Crossref]
8. Afrand M, Ling CP, Khosrotehrani S, Flores-Mir C, Lagravère-Vich MO. Anterior cranial-base time-related changes: A systematic review. Am J Orthod Dentofac Orthop 2014; 146: 21-32.e6. [Crossref]
9. Arat ZM, Rübendüz M, Arman Akgül A. The displacement of craniofacial reference landmarks during puberty: A comparison of three superimposition methods. Angle Orthod 2003; 73: 374-80.
10. Bhattacharya A, Bhatia A, Patel D, Mehta N, Parekh H, Trivedi R. Evaluation of relationship between cranial base angle and maxillofacial morphology in Indian population: A cephalometric study. J.Orthod Sci 2014; 3: 74-80. [Crossref]
11. Gong A, Li J, Wang Z, Li Y, Hu F, Li Q, et al. Cranial base characteristics in anteroposterior malocclusions: A meta-analysis. Angle Orthod 2016; 86: 668-80. [Crossref]
12. Dhopatkar A, Bhatia S, Rock P. An Investigation into the relationship between the cranial base angle and malocclusion. Angle Orthod 2002; 72: 456-63.
13. Klocke A, Nanda RS, Kahl-Nieke B. Role of cranial base flexure in developing sagittal jaw discrepancies. Am J Orthod Dentofac Orthop 2002; 122: 386-91. [Crossref]
14. Renfroe E. A study of the facial patterns associated with Class I, Class II, division 1, and Class II, division 2 malocclusions. Angle Orthod 1948; 18: 12-5.
15. Björk A. Some biological aspects of prognathism and occlusion of the teeth. Acta Odontol Scand 1950; 9: 1-40. [Crossref]
16. Ricketts RM. Facial and denture changes during orthodontic treatment as analyzed from the temporomandibular joint. J Maxillofac Orthop 1971; 4: 26-8.
17. Bastir M, Rosas A, O'Higgins P. Craniofacial levels and the morphological maturation of the human skull. J Anat 2006; 209: 637-54. [Crossref]

18. Thiesen G, Pletsch G, Zastrow MD, Valle CVM do, Valle-Corotti KM do, Patel MP, et al. Comparative analysis of the anterior and posterior length and deflection angle of the cranial base, in individuals with facial Pattern I, II and III. Dental Press J Orthod 2013; 18: 69-75. [Crossref]
19. Nanda R, Snodell SF, Bollu P. Transverse growth of maxilla and mandible. Semin Orthod 2012; 18: 100-17. [Crossref]
20. Costello BJ, Rivera RD, Shand J, Mooney M. Growth and development considerations for craniomaxillofacial surgery. Oral Maxillofac Surg Clin North Am 2012; 24: 377-96. [Crossref]
21. Huh YJ, Huh K-H, Kim H-K, Nam S-E, Song HY, Lee J-H, et al. Constancy of the angle between the Frankfort horizontal plane and the sella-nasion line: A nine-year longitudinal study. Angle Orthod 2014; 84: 286-91. [Crossref]
22. Andria LM, Leite LP, Prevatte TM, King LB. Correlation of the cranial base angle and its components with other dental/skeletal variables and treatment time. Angle Orthod 2004; 74: 361-6.
23. Zebeib AM, Naini FB. Variability of the inclination of anatomic horizontal reference planes of the craniofacial complex in relation to the true horizontal line in orthognathic patients. Am J Orthod Dentofac Orthop 2014; 146: 740-7. [Crossref]
24. Özsoy ÖP, Kaya B. Changes in cranial base morphology in different malocclusions. Orthod Craniofacial Res 2007; 10: 216-21. [Crossref]
25. Björk A. The significance of growth changes in facial pattern and their relationship to changes in occlusion. Dent Rec 1951; 71: 197-208.
26. Giri J, Pokharel PR, Gyawali R. Angular relationship between Frankfort horizontal plane and Sella-Nasion plane in Nepalese orthodontic patients: A cephalometric study. Orthod J Nepal 2018; 7: 14-7. [Crossref]
27. Alves PVM, Mazucheli J, Vogel CJ, Bolognese AM. A protocol for cranial base reference in cephalometric studies. J Craniofac Surg 2008; 19: 211-5. [Crossref]
28. Tian K, Li Q, Wang X, Liu X, Wang X, Li Z. Reproducibility of natural head position in normal Chinese people. Am J Orthod Dentofac Orthop 2015; 148: 503-10. [Crossref]
29. Gateno J, Xia JJ, Teichgraeber JF. New 3-Dimensional cephalometric analysis for orthognathic surgery. J Oral Maxillofac Surg 2011; 69: 606-22. [Crossref]
30. Cevidanes L, Oliveira AEF, Motta A, Phillips C, Burke B, Tyndall D. Head orientation in CBCT-generated cephalograms. Angle Orthod 2009; 79: 971-7. [Crossref]
31. Leitão P, Nanda RS. Relationship of natural head position to craniofacial morphology. Am J Orthod Dentofacial Orthop 2000; 117: 406-17. [Crossref]
32. Pelo S, Cacucci L, Boniello R, Moro A, Deli R, Grippaudo C, et al. BaS analysis: A new cephalometric study for craniofacial malformations. Child's Nerv Syst 2009; 25: 997-1006. [Crossref]
33. de Almeida KCM, Raveli TB, Vieira CIV, Dos Santos-Pinto A, Raveli DB. Influence of the cranial base flexion on class I, II and III malocclusions: A systematic review. Dental Press J Orthod 2017; 22: 56-66. [Crossref]
34. Wilhelm BM, Beck FM, Lidral AC, Vig KWL. A comparison of cranial base growth in Class I and Class II skeletal patterns. Am J Orthod Dentofac Orthop 2001; 119: 401-5. [Crossref]
35. Alia F, Aziz R, Malik A, Afzal H. Evaluation of cranial base morphology of Pakistani population in skeletal class I, II and III malocclusions. Orthod J Nepal 2019; 9: 43-6. [Crossref]
36. Góis EGO, Ribeiro-Júnior HC, Vale MPP, Paiva SM, Serra-Negra JMC, Ramos-Jorge ML, et al. Influence of nonnutritive sucking habits, breathing pattern and adenoid size on the development of malocclusion. Angle Orthod 2008; 78: 647-54. [Crossref]
37. Greiner P, Múller B, Dibbets J. The Angle between the Frankfort horizontal and the Sella-Nasion line. J Orofac Orthop der Kieferorthopädie 2004; 65: 217-22. [Crossref]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.19060

Original Article

Photographic Evaluation, Analysis and Comparison of Aesthetically Pleasing Smiles: A Prospective Study

Anisha Janu[1], Aftab Azam[2], Ragni Tandon[2], Pratik Chandra[2], Rohit Kulshrestha[3], Vinay Umale[4]

[1] Department of Dentistry, JLN Medical College and Hospital, Ajmer, Rajasthan, India
[2] Department of Orthodontics and Dentofacial Orthopedics, Saraswati Dental College, Lucknow, Uttar Pradesh, India
[3] Department of Orthodontics and Dentofacial Orthopedics, Terna Dental College, Navi Mumbai, Maharashtra, India
[4] Department of Orthodontics and Dentofacial Orthopedics, Yogita Dental College, Khed, Maharashtra, India

Cite this article as: Janu A, Azam A,Tandon R, Chandra P, Kulshrestha R, Umale V. Photographic Evaluation, Analysis, and Comparison of Aesthetically Pleasing Smiles: A Prospective Study. Turk J Orthod 2020; 33(3): 177-82.

ABSTRACT

Objective: To evaluate the differences in aesthetically pleasing smiles and compare the smile arc parameters in males and females by dental specialists using photographs.

Methods: The study was conducted on 500 North Indian subjects (Indo-Aryan race; 212 males and 288 females) aged 17-25 years (mean age, males=21.1 years; females=23.4 years), with reasonably pleasing smiles. The facial photographs were taken using a DSLR camera. The standardized photographs were shown to 30 judges for evaluation and rated using the visual analog scale. The smiles were categorized into attractive, fair, and average. The quantification of the smile characteristics was done by using an objective method that involved identifying consonant and non-consonant smiles.

Results: The association between smile arc and smile attractiveness was significant (p=0.018) in females. The buccal corridor width was higher among those with fair to attractive smiles as compared with those with an average smile (p=0.018). Most subjects with an attractive smile had a smile arc parallel to the upper lip as compared with most subjects with a fair or average smile who did not have the smile arc in parallel (p=0.006).

Conclusion: Most females were in the fair to attractive category whereas most males were in the average to fair category. The buccal corridor width was found to be higher among those with a fair to attractive smile as compared with those with an average smile. There was an association between smile arc and smile attractiveness in females.

Keywords: esthetics, photography, smiling

Main points:

- The buccal corridor width was higher among those with fair to attractive smiles as compared with those with an average smile.
- Most subjects with an attractive smile had a smile arc parallel to the upper lip.
- Most females were in the fair to attractive category whereas most males were in the average to fair category.
- There was an association between smile arc and smile attractiveness in females.

INTRODUCTION

The word "aesthetics" is derived from the Greek word for "perception", and relates with magnificent and charming characteristics. It has two aspects: objective and subjective (1). The objective (commendable) charm depends on the thought of the object itself, suggesting that the object has properties that make it without a doubt commendable. The subjective (delightful) grace is a quality that is esteem loaded and is with respect to the tastes of the individual thinking about it (2). An appealing and admirably adjusted smile is the principal aim of the treatment provided in present day orthodontic therapy (3). It is necessary to control the aesthetic results brought about by orthodontic therapy, which is achievable by knowing the rules that deal with the harmony among teeth and their adjacent soft tissue while smiling (4).

Address for Correspondence: Rohit Kulshrestha, Department of Orthodontics and Dentofacial Orthopedics, Terna Dental College, Navi Mumbai, Maharashtra, India
E-mail: id-kulrohit@gmail.com

Received: June 6, 2019
Accepted: March 30, 2020
Available Online Date: June 02, 2020

As indicated by the standards of visual recognition, a consonant and symmetric organization of teeth, visible gingival, buccal vestibular areas, and lips are a necessity for an aesthetic and gratifying smile. This smile creation is shaped by the lips in such a way that the arrangement of teeth and visible gingiva is customized by the profile of the lips and height of the smile line. The profile of the lips influences the visual establishment, for example, the buccal vestibule, smile arc, smile index, and the quantity of visible incisal edges (5). Furthermore, it was recently stated that the basic components in the self-impression of the smile allure are the visible teeth, buccal vestibular space, smile arc, and position of the upper lip (6-8). A comprehensive way to deal with orthodontic practice would not just be to treat the malocclusion present in the teeth, but also to manage the profiles of people that impact the individuals' bearing and prosperity. The early hypothesis of aesthetics encircled around the patient's facial contour and it was thought that once the perfect tooth jaw positions were attained, the soft tissues would also align (9). In recent times, the frontal assessment as well as the profile evaluation has been given equal value. Smile analysis is one of the chief elements of a frontal facial evaluation.

There are two forms of smiles, the happiness or Duchene smile and the presented/posed or social smile (10). The posed smiles have acquired significance in dentistry and orthodontics fundamentally on the grounds that they are replicated easily after some time. Ample consideration has been given to the clinical examination of the visible zone of smile, which is decided by the inter-commissural width, smile arc, inter labial distance, smile index, and visible gingival. Examining the smile and acquiring the midpoints for different smile portions give a recommendation regarding the standard of a normal pattern to fill in as a rule for the production of an aesthetically pleasant smile. A study conducted by Hulsey et al. (11), in which he evaluated the smile arc and aftereffects of his examination, demonstrated that the patients who were treated orthodontically had a low smile quotient than the untreated patients. Rigsbee et al. (12) reasoned that in an alluring smile, the upper lip was raised to uncover 10 mm of the maxillary incisors, the mouth expanded to 30% of its actual width, and the lips were separated by approximately 12 mm. Very little literature is available on the gender differences in smiling and the variability of smiling morphology in humans. Hence, to bring clarity on this topic, this study was done to evaluate the smile characteristics of males and females using frontal view photographs of smiles and also to compare the smile arc for consonant and non-consonant smiles.

METHODS

The study was carried out on 500 patients taken from the Department of Orthodontics and Dentofacial Orthopedics (212 males and 288 females after performing a power analysis) between the ages of 17 and 25 years (mean age for males=21.1 years; females=23.4 years) with reasonably pleasing smiles. The pleasing smile was considered for incisor crowding, incisor display, gummy smile, and lip contours. The patients who had normal values of the abovementioned parameters were enrolled in the study. The study was approved by the Institutional Ethics Committee; the patients were educated before the study, and informed consent forms were signed and obtained. All the subjects were selected with the following inclusion criteria: no previous orthodontic treatment; Decayed Missed Filled Teeth (DMFT) Index by Klein, Palmer, and Knutson of zero; ideal overjet and overbite; complete permanent dentition with or without a third molar; good oral hygiene; and no canting of the maxillary occlusal plane. The patients who fit in the above inclusion criteria were included in the study. The rest were excluded. The facial photographs of 500 subjects were taken using a Nikon SLR 3200D digital camera in the photography room of the college (Figure 1). The records of the subjects were taken in the form of posed smile photographs (in the light of the fact that the presented posed smiles are the most repeatable) after seating them in a cephalostat with a natural head position. The photos of presented smiles were recorded in the same domain with an identical background. The camera along with a tripod was fixed at a location, and all the snapshots were recorded in color. The photos were moved to the computer software (Adobe Photoshop, version 7, Adobe Systems, San Jose, California, USA) where they were cut short upright and horizontally by taking into consideration the nose tip and soft tissue pogonion and a perpendicular drawn down from the zygomatic prominence respectively as limits. All images were taken at a real smile (1:1 ratio) life size; hence, there was no magnification error. The ruler and pointer in the software were utilized to get all the estimations for this examination.

The index related to the smile put forward by Ackerman and Ackerman (7) is measured by dividing the inter-commissural width/breadth by the inter-labial width/height (Figure 2). We utilized an improved form of the smile index, called the measured smile index, as a portion of the refinement to incorporate the lips and calculated the inter-vermilion extent/distance at the midline for height and inter-commissural distance for width.

Modified Smile Index=Inter-commissural width/Inter-labial gap X 100

The buccal corridor width was also measured by joining the lines from the buccal aspect of the posterior teeth to the angle of the mouth in the photos. The amount of incisor display was calcu-

Figure 1. a, b. Unattractive smile photos (a) and, attractive smile photos (b)

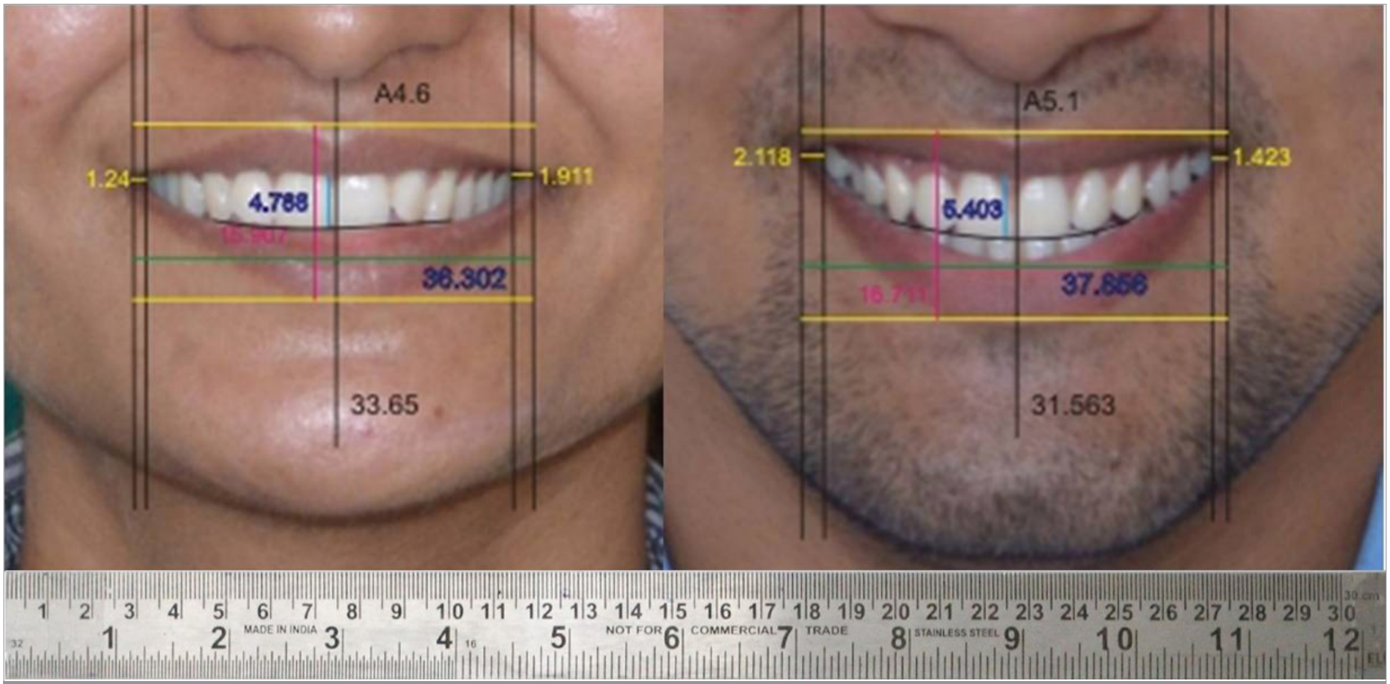

Figure 2. Standardized photographs with measurements

lated by drawing a line from the center of the upper lip perpendicularly downward to the midpoint of the incisal edges of the maxillary incisors. A consonant smile is described as that when the smile arc of the maxillary anterior teeth at the incisal edges are inline or equal to the curvature of the upper lip line. All 500 standardized photographs were shown to a panel of judges for evaluation via a projector for 20 seconds each in several different sessions. The panel comprised 6 orthodontists, 6 oral and maxillofacial surgeons, 6 prosthodontists, 6 beauticians, and 6 lay persons (mean age=35.5 years; 3 males and 3 females in each group). No communication between the panelists was allowed during the evaluation. The panelists were given a blueprint with a visual analog scale (VAS) varying from 1 to 10 (1=worst; 10=very good) to assess these smiles. The VAS was briefly elucidated using a few words to the panel members, with many demonstrations before starting. The smiles were categorized into attractive, fair, and average smiles based on the VAS scores, <3=average; 4-6=fair; >7=attractive. The grouping was done to simplify the categories as the sample size was large to calculate each one individually. A prospective power analysis using the Power and Precision software (version 2.0, Power and Precision, 2000, developed by Borenstein) was done to find the interrelationship for comparing the modified smile index and if the other indexes were correct. For this reason, the *p* value was positioned at 0.05 (2 tailed). To check for an error in the assessment of photos, 20 photos were showed to each judge again after a period of 10 days to check for reliability. No difference was seen in the assessment given by the judges for both the photos.

Statistical Analysis

The statistical analysis was performed with the Statistical Package for Social Sciences, version 16.0 software (SPSS Inc.; Chicago,IL, USA). The gender-wise comparison of the VAS scores was done to find the statistical significance between males and females. An analysis of variance (ANOVA) analysis with a post hoc evaluation was performed between different parameters of males and females. A group comparison of different parameters of both genders was done using the measures of dispersion mean and standard deviation along with the test of significance to obtain the desired results. For the group-wise perception of the evaluators, the number of evaluators was too small to get any significant difference (n=6). The perception of the smile based on the gender of the evaluators was compared using a Student paired *t* test, and a statistically significant difference was seen.

RESULTS

Most females had VAS scores in the fair to attractive category whereas most males had VAS scores in the average to fair category (Figure 3). Statistically, this difference was significant (p=0.012) (Table 1). The buccal vestibular width (left side) was established to be more including those with a fair to charismatic smile as compared with those with an average smile (p=0.018) (Table 1). Most females with a parallel smile arc had an attractive smile while most females who did not have a parallel arc had an average to fair smile; this association between smile arc and smile attractiveness was significant (p=0.018). In males, the proportion of attractive smiles was higher for the parallel smile arc as compared with those not having a parallel smile arc, but this association was not statistically significant. Most subjects with an attractive smile had a parallel smile arc as compared with most subjects with a fair and average smile who did not have a parallel smile arc (p=0.006).

DISCUSSION

The reappearance of the soft tissue pattern in clinical orthodontics has made smile analysis a chief component in detection and therapy (13, 14). In our study, we assessed different qualities of a smile using two techniques. Most females had VAS scores in the

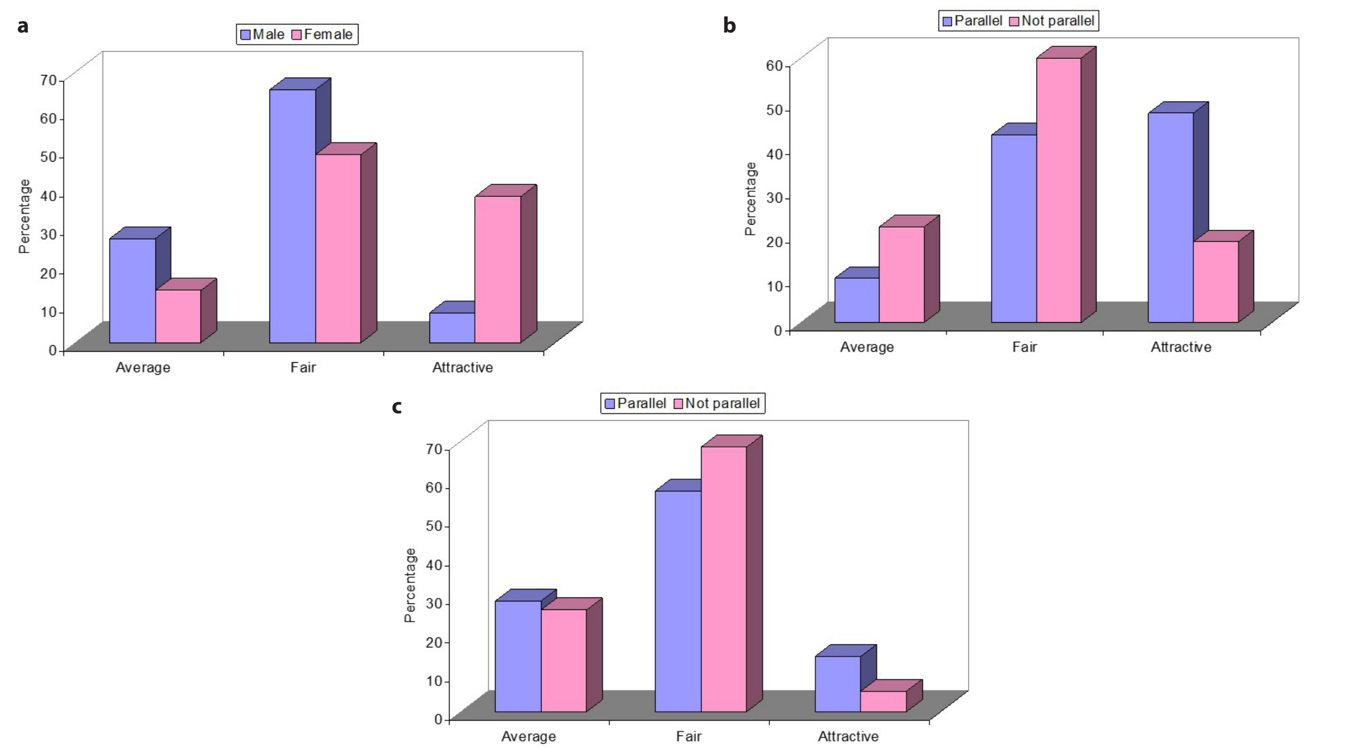

Figure 3. a-c. Gender-wise comparison of the VAS scores (a), smile arc and VAS scores (females) (b), and smile arc and VAS scores (males) (c).

Table 1. Comparison of different parameters among different categories of the VAS Scores (both genders)

	Average (n=140)		Fair (n=230)		Attractive (n=130)		ANOVA	
Parameter	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**F**	**p**
Incisal exposure	7.12	2.07	7.57	2.07	7.60	1.78	0.381	0.684
BCR	4.01	0.82	4.50	1.31	4.30	1.35	1.033	0.360
BCL	3.52	0.94	4.34	1.26	4.52	1.16	4.160	0.018*
Average BC	3.77	0.79	4.42	1.22	4.41	1.17	2.285	0.107
Inter-labial width	24.92	2.46	25.75	3.21	24.47	2.43	2.006	0.140
Inter-commissural width	56.74	7.25	58.56	6.19	58.36	5.26	0.587	0.558
Smile index	44.44	6.04	44.20	5.51	42.15	4.71	1.628	0.202

BCR: buccal corridor width (right); BCL: buccal corridor width (left); BC: buccal corridor
*Significant at p<0.05

fair to attractive category whereas most males had VAS scores in the average to fair category. Our outcomes concur with those of Krishnan et al. (15), who expressed that the female smile appears to be extra appealing and in harmony than the male smile. Similarly, Geron and Atalia (16) determined that the gender of the imitation smile photo influences the smile allure as they used females as the only model image. We inferred that the perception of attractiveness is biased by the gender of an individual. Smile in a gender perspective is perceived differently as has been elucidated by Dong et al. (17), who found the difference in the perception of attractiveness and personality judgment of the two genders. Similar perception differences based on the gender were also observed in several other studies (18, 19). In a study by Maulik and Nanda (20), smile components were compared between the genders and they found a rationally notable distinction between them in every smile element examined. A greater anterior smile line was seen in females by Peck and Peck (21), and our findings were in accordance with theirs. Females demonstrated a greater rate of an inverse smile arc. In addition, we noted that females show a smaller buccal vestibule than males.

In an examination by Parekh et al. (22), the gender of the model possibly showed significance when the smile arc was similar, and the buccal vestibule was desirable. Under these circumstances, the male buccal corridor width was unappealing due to greater visibility of the buccal vestibule than that noticed in females. In this study, we assessed accordance and discordance in the smile arc association. The word accordance explains the parallel correlation between the contour of the maxillary incisal edge and contour of the lower lip while smiling. In discordance or a flat smile, the same correlation was noted straight upon smiling. In a study conducted by Tjan et al. (23), the authors stated that adults show a greater (85%) maxillary incisal smile curve parallel to the inner curvature of the lower lip. Around 14% of cases presented a flat line instead of a curved line and only 1% of cases showed an inverse smile curve. It is familiar that an in-accordance smile arc appears stunning rather than a straight/flat smile (15). A greater number of women showed an appealing smile than men. Most subjects with an attractive smile had a parallel smile arc as compared with most subjects with a fair and average smile who did not have a parallel smile arc.

In our study, the majority of females with a parallel smile arc had attractive smiles while most females who did not have a parallel smile arc had average to fair smiles. Our findings are in agreement with those of Krishnan et al. (15) who established that the female smile is more in harmony and attractive than the male smile. Ackerman and Ackerman (7) revealed that through orthodontic or restorative therapy, the arc of maxillary incisal edges can be modified. Several researchers have also laid emphasis on consonance as the key feature of an aesthetic smile (24, 25). To evaluate the frontal smile by visualizing, Ackerman and Ackerman (7) established a proportion, called the smile index, which portrays the zone encircled by the vermilion borders of the lips during the social smile.

Nowadays many studies are being done by researchers to find the effects of the buccal vestibule on smile aesthetics. All reports demonstrate that buccal vestibules have no impact on the aesthetic assessments of smiles. Parekh et al. (22) discovered that the width of the buccal vestibule had a critical effect just when the smile arc was perfect for men. Whereas in females, all buccal vestibule width with a perfect and intemperate smile arc was observed to be in the upper levels of the attractiveness range. This was valid for men with the exception of when the buccal vestibule areas ended up being intemperate. In a study, Oshagh et al. (26) found that the impact of features such as the buccal corridor width is perceived differently for male and female subjects. In this study, in spite of the fact that we could not locate a noteworthy relationship between the charm and buccal corridor widths for the two genders independently, an overall significant association between the left buccal corridor width and attractiveness was observed, favoring the proposed relationship that the larger buccal corridor was related to an attractive appearance. In females, these trends were quite clear, though not significant statistically.

In our study, among all the criteria, only the buccal vestibule width was observed to be statistically noteworthy. In a study performed by Krishnan et al. (15), when the smiles of both the sexes were juxtaposed for their buccal vestibular values, they observed a high relationship, which could not help but contradict their VAS measurements. The values demonstrated a remarkable contrast between the apparent smiles of men and women. Consequently, we can presume that the buccal vestibular space plays an insignificant role in the aesthetic assessment of a smile and the apparent distinction could be because of different reasons, for example, smile arc, alignment of teeth, shades of tooth, gingival structure, visible gingiva, and density of lips.

Graber et al. (27) stated that the factors that may influence the measurement of the buccal corridor space are the background light specifics in which the photos were taken. As the teeth are situated more posteriorly in the buccal vestibule, the light ends up diminished, which leads to continuous obscuring and subsequently less perception of these posterior teeth. Less light is focused on the photo, and thus, the negative space is greater as fewer teeth would be noticed. Hence, there may have been dissimilarities in the calibration of the light conditions. The other factors that may impact can be the kind of smile examined, in particular, a constrained smile, which is in our study easily reproducible, and a genuine smile as portrayed in the investigation by Johnson and Smith (28), which is a lot harder to recreate. The limitation of this study was that it was performed on a specified population. Further studies can be done on the general population and with a larger sample size.

CONCLUSION

- Most females were in the fair to attractive category whereas most males were in the average to fair category. Statistically, this difference was significant.
- In both males and females, an increased buccal corridor width was found in attractive smiles.
- There was an association between smile arc and smile attractiveness in females. More females had consonant smiles than males.

Ethics Committee Approval: The study was approved by the Institutional Ethics Committee of Saraswati Dental College and Hospital Lucknow UP.

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception – A.J., A.A.; Design – A.A.; Supervision – R.T., P.C; Data Collection and/or Processing – P.C., R.K.; Analysis and/or Interpretation – R.K.; Writing Manuscript – V.U.; Critical Review – R.K.; Literature Search – A.J.

Conflict of Interest: The author has no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Nash DA. Professional ethics and esthetic dentistry. J Am Dent Assoc 1988; 115: 7E-9E. [Crossref]
2. Pogrel MA. What are normal esthetic values? J Oral Maxillofacial Surg 1991; 49: 963-69. [Crossref]
3. Roden-Johnson D, Gallerano R, English J. The effects of buccal corridor spaces and arch form on smile esthetics. Am J Orthod Dentofacial Orthop 2005; 127: 343-50. [Crossref]
4. Ritter DE, Gandini LG, Pinto Ados S, Locks A. Esthetic influence of negative space in the buccal corridor during smiling. Angle Orthod 2006; 76: 198-203.
5. Van der Geld P, Oosterveld P, Schols J. Smile line assessment comparing quantitative measurement and visual estimation. Am J Orthod Dentofacial Orthop 2011; 139: 174-80. [Crossref]

6. Stallard H. Survival of the periodontium during and after orthodontic treatment. Am J Orthod 1964; 50: 584-92. [Crossref]
7. Ackerman MB, Ackerman JL. Smile analysis and design in the digital era. J Clin Orthod 2002; 36: 221-36.
8. Sarver D, and Ackerman MB. Dynamic smile visualization and quantification: part 1. Evolution of the concept and dynamic records for smile capture. Am J Orthod Dentofacial Orthop 2003; 124: 4-12. [Crossref]
9. Zachrisson BU. Esthetic factors ınvolved in anterior tooth display and the smile: vertical dimension. JCO 1998; 32: 432-45.
10. Frush JP, Fisher RD. The dynesthetic interpretation of the dentogenic concept. J Prosthet Dent 1958; 8: 558-81. [Crossref]
11. Hulsey CM. An esthetic evaluation of lip-teeth relationship present in the smile. Am J Orthod 1970; 57: 132-144. [Crossref]
12. Rigsbee OH, Sperry TP, Begole EA. The influence of facial animation on smile characteristics. Int J Adult Orthodont Orthognath Surg 1988; 4: 233-39.
13. Sarver DM. The importance of incisor positioning in the esthetic smile: the smile arc. Am J Orthod Dentofacial Orthop 2001; 120: 98-111. [Crossref]
14. Schaebel BJ, McNamara JA Jr, Franchi L, Baccetti T. Q sort assessment vs visual analog scale in the evaluation of smile esthetics. Am J Orthod Dentofacial Orthop 2009; 135: 61-71. [Crossref]
15. Krishnan V, Daniel ST, Lazar D, Ashok A. Characterization of posed smile by using visual analog scale, smile arc, buccal corridor measures, and modified smile index. Am J Orthod Dentofacial Orthop 2008; 133: 515-23. [Crossref]
16. Geron S, Atalia W. Influence of sex on the perception of oral and smile esthetics with different gingival display and incisal plane. Angle Orthod 2005; 75: 778-84.
17. Dong JK, JIn TH, Cho HW, Oh SC. The esthetics of the smile: a review of some recent studies. Int J Prosthodont 1999; 12: 9-19.
18. Peck S, Peck L. Selected aspects of the art and science of facial esthetics. Semin Orthod 1995; 1: 105-26. [Crossref]
19. Dickens ST, Server DM, Proffit WR. Changes in frontal soft tissue dimensions of the lower face by age and gender. World J Orthod 2002; 3: 313-20.
20. Maulik C and Nanda R. Dynamic smile analysis in young adults. Am J Orthod Dentofacial Orthop 2007; 132: 307-15. [Crossref]
21. Peck S, Peck L and Kataja M. The gingival smile line. Angle Orthod 1992; 62: 91-100.
22. Parekh SM, Fields HW, Beck M, Rosential S. Attractiveness of variations in the smile arc and buccal corridor space as judged by orthodontist and laymen. Angle Orthod 2006; 76: 557-63.
23. Tjan AH, Miller GD, The JG. Some esthetic factors in a smile. J Prosthet Dent 1984; 51: 24-8. [Crossref]
24. Machado AW. 10 commandments of smile aesthetics. Dent Press J Orthod 2014; 19: 136-57. [Crossref]
25. Moskowitz ME, Nayyar AA. Determinants of smile esthetics: a rationale for smile analysis and treatment. The compendium of continuing education in dentistry 1995; 16: 1164-66.
26. Oshagh M, Zarif NH, Bahramnia F. Evaluation of the effect of buccal corridor size on smile attractiveness. Eur J Esthet Dent 2010; 5: 370-80.
27. Graber LW, Lucker GW. Dental aesthetics self-evaluation and satisfaction. Am J Orthod 1980; 77: 163-73. [Crossref]
28. Johnson DK, Smith RJ. Smile aesthetics after orthodontic treatment with or without extraction of first four premolars. Am J Dentofacial Orthop 1995; 108: 162-167. [Crossref]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.19059

Review

Up-to-Date Approach in the Treatment of Impacted Mandibular Molars: A Literature Review

İpek Tamer, Evren Öztaş, Gülnaz Marşan

Department of Orthodontics, İstanbul University İstanbul School of Dentistry, İstanbul, Turkey

Cite this article as: Tamer İ, Öztaş E, Marşan G. Up-to-Date Approach in the Treatment of Impacted Mandibular Molars: A Literature Review. Turk J Orthod 2020; 33(3): 183-91.

ABSTRACT

Eruption problems in the mandibular molars are rare, but they have to be diagnosed and treated early. Treatment of impacted molars is challenging due to a limited access and complexity of the mechanics that needs to be applied. Methods for managing impacted or tilted mandibular molars include orthodontic repositioning, surgical uprighting, and extraction with or without transplantation of the third molar into the extraction site.

This review highlights the methods and clinical procedures of surgical and orthodontic uprighting procedures of mandibular molars with different degrees and levels of impaction. It further discusses the use of the ramus screw as a temporary anchorage device in the uprighting of horizontally impacted mandibular molars.

Keywords: Impacted teeth, mandibular, molar uprighting, orthodontics, ramus screws

INTRODUCTION

Impaction of permanent teeth is a complex problem, refractory to routine orthodontic treatment, and it must be managed effectively. Relative incidence of impaction is the highest for maxillary and mandibular third molars, followed by maxillary canines and lower second molars (1). Second-molar impaction is a very rare condition occurring prevalently in the mandible, and its prevalence ranges between 0.06% and 0.3% of the population, but a higher ratio has been reported in orthodontic patients (2%-3%) (1, 2). Although the consequences are rare, there are many functional, periodontal, hygienic, and prosthodontic reasons justifiying the need for treatment of impacted mandibular molars.

Aetiology of Molar Impaction

The major ethiologic factor in second-molar impaction is the lack of space. The space required for the eruption of second molars is provided via the aposition and resorption procedures. Any interuption during these procedures results in eruption problems of molars (3). An inadequate mesial movement of first molars due to ankylosed deciduous molars or early loss of primary molars may lead to eruption disturbances of molars (4). Other local factors in second-molar impactions are the ectopic position, obstacles in the path of eruption, such as an odontogenic tumor or cyst, and morphologic anomalies such as root invaginations or deflections (5, 6). Systemic factors such as syndromes related to multiple tooth impactions and mutations of the PTH 1 receptor may also contribute the eruption failure of molars. If the impaction is bilateral and involves both arches, a systemic or genetic etiology is likely (7).

Iatrogenic factors also play an important role primarily in second-molar impactions. An incorrectly fitted band cemented on the first mandibular molar may give rise to eruption problems in second molars (8). In addition, the orthodontist may inadvertently impact a second molar while attempting to increase the mandibular length with a lip bumber or the Arnold appliance (9, 10).

Address for Correspondence: İpek Tamer, Department of Orthodontics, İstanbul University İstanbul School of Dentistry, İstanbul, Turkey
E-mail: ipek639@gmail.com

Received: October 16, 2019
Accepted: November 10, 2019
Available Online Date: 21.05.2020

Diagnosis of Impacted Lower Mandibular Molars and the Need for Treatment

Impacted second lower molars are typically diagnosed between 11 and 14 years of age, and they are rarely the seldom concern for orthodontic referral. Being an asymptomatic pathology, they are generally diagnosed as a secondary finding during an orthodontic examination (11).

The absence of one molar while the contralateral is normally erupted should alert the orthodontist for molar impaction, and eruption of the molar should be evaluated by orthopantomographic radiography.

In a panoramic evaluation of a preadolescent, if a lower third-molar follicle is positioned on top of the developping second-molar crown, this situation is also an early warning of a future impaction (Figure 1) (12).

As an impacted lower second molar is diagnosed, the treatment option should be either uprighting via orhodontic or surgical procedures, extraction of the impacted tooth and restoring the space via prosthodontic solutions, or orthodontic third-molar mesialization. To the best of our knowledge, there is no literature supporting the extraction of a healthy impacted tooth in the favor of placing an implant. Uprighting impacted molars also prevent the possible neurologic injury, which could be caused by closed proximity to inferior alveolar nerve. Uprighting the tooth primary to extraction facilitates the surgical procedure and precludes potential injuries to the roots of adjacent molars (6).

Untreated impacted lower molars bring about the risks of periodontal problems, tooth decay, and external root resorption in the adjacent molar roots (8). Literature proves that mesially impacted lower molars accentuate the periodontal bone loss, which increases the risk of pericoronitis and immigration of inflamatuary cells by causing supra- and subgingival plaque accumulation, thus badly affecting the bone level of adjacent molar (13). Uprighting of inclined molars decreases the pocket depth by 0.1 mm on each tooth surface, facilitating the plaque control (14).

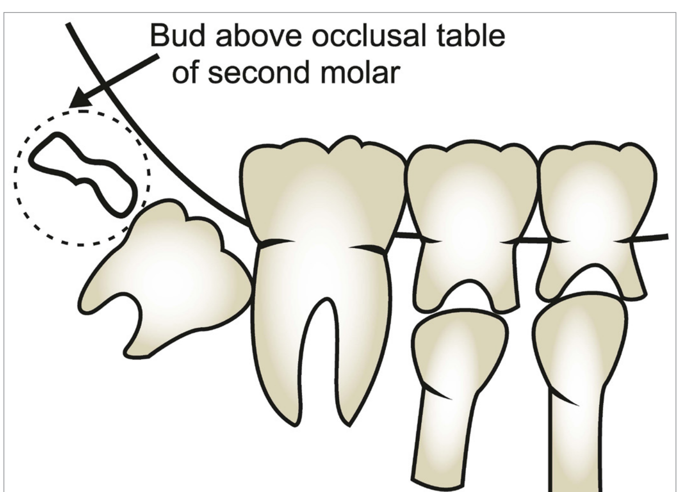

Figure 1. Lower third molar follicle positioned on top of the second molar, an early sign of second molar impaction

Besides the periodontal advantages, uprighting molars allows the parallel placement of dental implants, idealizing the prosthodontic rehabilitations; hence, occlusal forces are equally distrubuted, and the resistance of teeth to masticatory forces increase. Uprighting of inclined molars also eliminates primary contacts, thus preventing traumatic occlusion and TMJ problems (15). Uprighting of lower molars plays an important role in the establishment of vertical dimension.

Treatment of Inclined or Impacted Molars

Classification of Impacted Molars

Classifying the degree of impaction determines the level of complexity of the problem and facilitates the desicion making in the favor of extracting or uprighting. The relative position of molar impaction is assessed using the Pell–Gregory and Winters Classifications (16, 17).

Winters (16) classified impacted molars according to their angulations, being vertical, horizontal, distoangular, mesioangular, buccoangular, or linguangular. The classification by Pell–Gregory (17) is a two-phased classification and categorizes both the depth of the impaction and its relationship with the mandibular ramus. In this classification, the depth of impaction ranges between Classes A, B, and C, from superficial to deep (Figure 2).

When making a desicion on the uprightability of an impacted molar, especially in horizontal impactions, the depth of impaction should be the primary concern. According to this classification, Position B is the best candidate for uprighting, whereas Position A, although the most superficial, is the worst. Uprighting a molar that is horizontally and superficially impacted may result in occlusal traumas.

Position C, being the deepest, is the most favorable for uprighting mechanics; however, conventional orthodontics is insufficient, and the ramus bone screw anchorage is needed (18). When an impacted molar is encountered, position B is the easiest to upright even with conventional mechanics, however with the improvements like ramus screws position C ,although more difficult , is still uprightable.

Treatment Options for Impacted Molars

Extraction or uprighting of an impacted molar is the most critical desicion in the treatment planning. Factors affecting this desicion are the degree of impaction, the relationship of the tooth with the critical anatomic structures (inferior alveolar nerve, lingual arteria), caries, root dilacerations, and periodontal problems. The complexity of the surgical procedure in the case of extraction should also be considered (19).

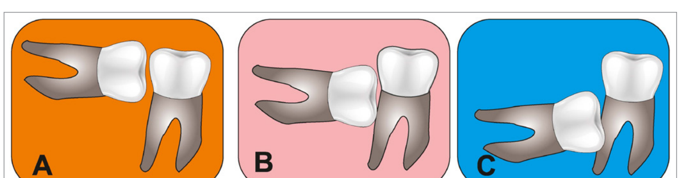

Figure 2. Pell- Gregory classification

Extraction is an alternative for impacted molars, which appears to have no chance of uprighting; in this case, if the second molar is extracted, the third molar may be allowed to erupt in the second molar position (20). However, if there is a time lapse between the extraction of the second molar and the eruption of the third molar, the third molar may not take the position of the second molar, and it may still stay impacted or inclined (20). On the contrary, Orton and Gibbs' study states that none of the third molars is impacted due to the extraction of an impacted second molar (21). Even so, each case should be evaluated carefully and individually. Extraction of an impacted molar followed by a prosthodontic rehabilitation is another utilizable alternative. However, to the best of our knowledge, no literature supports the placement of an implant in the place of an impacted molar that can succesfully be uprighted via orthodontic and surgical procedures.

A healthy tooth has a chance to serve a lifetime, whereas implants lead to various risks of failure due to periimplantitis, either patient or doctor related (22). Therefore, if impacted molars can be uprighted either surgically or orthodontically, they definetely should.

There are orthodontic and surgical treatment options for this difficult problem. Surgical alternatives range from simply uncovering the tooth to repositioning and uprighting it surgically.

Surgical Uprighting of Impacted Molars

Surgical uprighting is a fast and effective treatment alternative in cases where orthodontic treatment is contraindicated, patient cooperation is inadequate, or the molar is submerged deep below the soft tissue. This method is a safe and efficient solution with minimal tooth morbidity and a good long-term prognosis (12).

Although surgical uprighting is most commonly applied in mesially impacted lower second molars, it is also applicable in other impacted teeth that have a limited access or that did not respond to conventional orthodontic methods (12). A surgical uprighting procedure is generally applied by an oral surgeon and defined as luxation of an impacted tooth within its socket using a straight elevator (Figure 3).

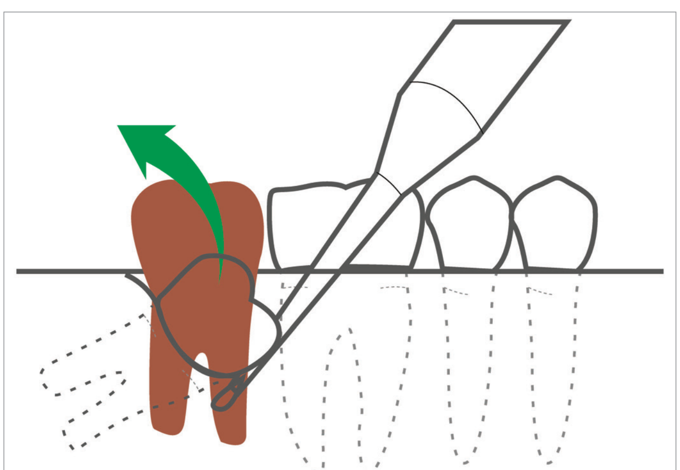

Figure 3. Illustration of surgical uprighting procedure

Prior to luxation, a minimal amount of bone is removed around the crown, ensuring that the cementomenamel junction and root surfaces are covered with bone. The tooth is tipped distally and superiorly until the occlusal surface is approximately level with the occlusal plane. The difference between this method and autotransplatation or transalveolar transplatation is that this technique is applied only within the tooth socket (12).

Since the tooth is not removed from its socket, the apical vessels remain intact, and saliva contamination of the roots is prevented; thus, it has a better long-term prognosis compared to autotransplatation (23).

Surgical Technique

Prior to the surgical procedure, lower brackets are bonded until the first molars, and leveling should be completed.

Surgery is performed under local anesthesia. A full thickness flap is extended, and the adjacent third molar should be removed to facilitate the uprighting of the second molar. Research indicates that the third molar is only to be extracted if it hinders the uprighting of the second molar. The third molar acts as a support for the previously impacted molar, and it contributes to the primary stability. Also, if the uprighted molar is extracted for any reason after the surgical uprighting, the third molar may be used in its position (23).

Prior to uprighting, an electric handpiece is used to remove the bone around the crown. A straight elevator is than placed mesially to the second molar, and in a slow and controlled manner, the tooth is tipped superiorly and distally, bringing it to its ideal position. The second molar is bonded immediately following the luxation, and the leveling procedures are continued on nickel–titanium (Niti) archwires.

Orthodontic Procedure

The first orthodontic appointment is scheduled 7–14 days following the surgery. A 0.014 or 0.018 NiTi is than applied for stabilization and improved alignment. Routine orthodontic appointments are scheduled every 6–8 weeks afterwards. Panoramic radiographs should be taken to assess bone health, and tooth vitality should be controlled (12). Bone formation should be seen in the mesial and distal parts of the impacted tooth after 9–10 months. Fixed appliances could be removed after the bone formation. Due to the previous position of the tooth, an acutely angled osseous defect is seen on the mesial side. It regenarates after the uprighting, but in the case of periodontitis, healthy periodontal attachement is not observed. In this case, surgical uprighting may worsen the present defect. Thus, surgical uprighting is contraindicated in periodontitis cases (24).

Risks and Complications of Surgical Uprighting

The primary risks of surgical uprighting are pulpal necrosis, external root resorption, and ankylosis. Although peridontal healing complications and the need for root canal treatment for the uprighted tooth are rare, an advanced age, completed root formation, and excessive inclination may cause an irreversible strain in the apical vessels and result in negative prognosis (25).

In the retrospective cohort study of Padwa et al. (25), radiographic outcomes of surgical uprighting are assesed. According to the study results, surgial uprighting is succesful in all the cases, and they stay healthy in the 1-year follow-up period.

Orthodontic Treatment of Impacted Molars

The best timing for treating impacted first and second molars is between 11 and 14 years of age, when the root formation is still not completed. The type of treatment depends on the tilt of the tooth, the degree of impaction, and the amount of orthodontic tooth movement needed (26).

When choosing the treatment mechanics, required tooth movements should be evaluated in three spatial planes (26). Molar uprighting should be the result of an appropriate combination of sagittal and vertical tooth movements.

Minor malpositions on second molars can be corrected by positioning an elastic separator in between two teeth, while more severe malpositioning demands the use of surgical methods or orthodontically assisted eruption techniques (27).

Orthodontically assisted eruption is one of the most efficient treatment options for impacted mandibular molars. This procedure can be done with or without surgically uncovering the impacted tooth. The general approach is to bond an attachment on the buccal or distobuccal surface of the impacted tooth, followed by the application of an uprighting force. The uprighting force can be delivered by simple tip back cantilever bends, a Niti coil spring, a superelastic Niti archwire, or various uprighting springs and segmental mechanics (26).

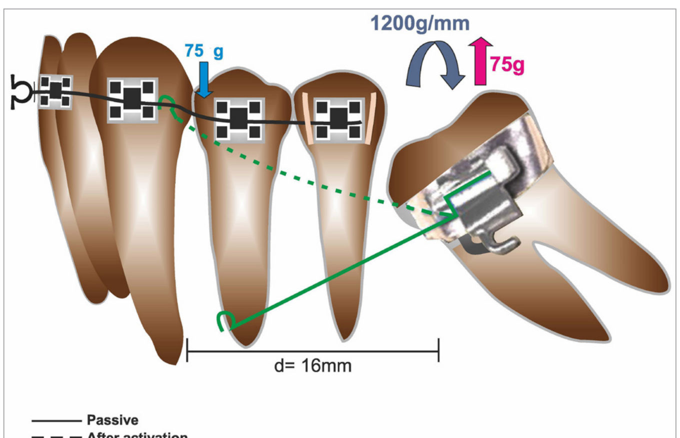

Figure 4. One cantilever force system

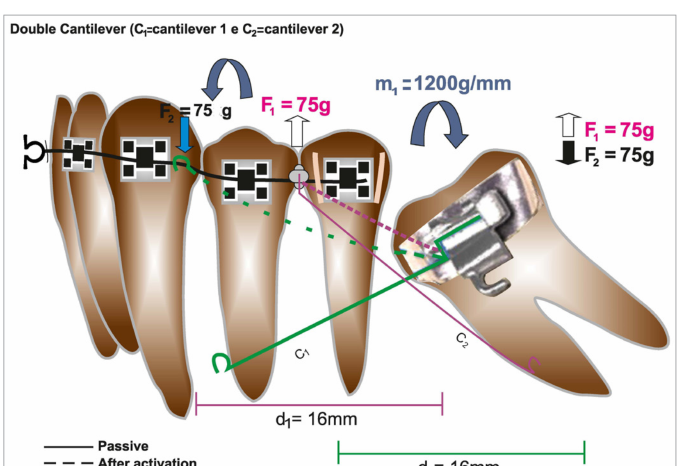

Figure 5. Two cantilever force system

Apart from these methods, various types of uprighting springs, such as Australian uprighting spring, cantilever spring, Sander spring, helical uprighting spring, or push spring, can be utilized (15).

Uprighting Mandibular Molars Using Simple Cantilever Mechanics

The 0.017*0.025 TMA archwire is used in all types of cantilever bends for molar uprighting due to its ability to deliver a lighter, continuous force and higher springness compared to stainless steel wires. Since cantilever uprighting springs are used as an auxillary archwire, the main archwire should always be a full-dimensional stainless steell wire. A 0.019*0.025 inch wire is recommended when working with the 0.022-slot dimension, while a 0.017*0.025 inch wire is suitable when using brackets with the 0.018-slot dimension. Cantilever springs generate tooth movement in three spatial planes: distal crown tipping in the mesiodistal direction, and extrusion in the vertical plane (26). They generate a force, but most importantly a moment to tip the molar to its correct position. The length of the cantilever determines the moment–force ratio. A shorter cantilever causes a greater extrusion force compared to a longer one (27).

All simple cantilever mechanics genetrate an extrusive force as the inclination of the molar is corrected, frequently necessinating occlusal adjustments during the treatment. Extrusion is an inevitable side effect of cantilever mechanics, but it does not cause serious problems in the majority of cases (28). Molar extrusion is a desired side effect if the tooth is below the functional occlusal plane, for example when the molar has been impacted following sagittal expansion or lip bumper theraphy (26).

In such cases, simple tip back mechanics can be used; however, if the tipped molar is above the functional occlusal plane, intrusion of the molar will be needed, requiring more complex mechanics (28).

Two different force systems are used in the Cantilever mechanics:

1. One Cantilever Force System (Figure 4)
2. Two Cantilever Force System (Figure 5)

The one cantilever force system is a simplified way to apply a segmented arch technique. In this type of cantilever, a moment to tip the molar into its correct position is generated, and along with its activation, a vertical force is generated causing the molar to erupt vertically (29). To prevent this extrusive moment, a counteracting intrusive force is required (Figure 4).

In 1992, Weiland et al. (15) reported that the extrusive force caused by the cantilever can be cancelled by a second cantilever. A second cantilever is placed between the bicuspids, and the loose end is attached to a piece of SS wire in the molar band, acting as an opposite force creator to the first cantilever (Figure 5). The two cantilever system is designed to overcome the side effects of uprighting cantilever springs on premolars: while the first cantilever produces extrusion of the molar, second cantilever neutralizes this effect.

When both springs are activated equally, vertical forces will cancel each other, and no extrusive force will be seen on the tipped molar (15, 29).

Besides, the mechanical advantages of applying two cantilevers may cause soft tissue irritations and thus be an uncomfortable option for the patient. The Sander spring, being a more comfortable and neater alternative, may be used instead (26).

In patients with a strong muscle pattern, occlusal forces are found to be effective in the prevention of extrusion; however, in patients with a weak muscular activity, extrusion should be prevented with additional mechanics (30). Since cantilever mechanics use the archwire as an anchorage unit, the unwanted side effects on the anchorage unit can be eliminated using skeletal anchorage. For patients treated with one or two cantilever mechanics, interdental mini implants can also be used to prevent the undesired side effects (31).

Skeletal Anchorage in the Treatment of Impacted Molars

Uprighting molars require a great amount of anchorage control. Ankylosed teeth, dental implants, and mini implants are useful in providing the absolute anchorage for uprighting and avoiding undesired tooth movements (10). Since this kind of anchorage control is not possible in conventional molar uprighting methods, reciprocal tooth movements in anchorage units and undesired extrusion of teeth may be encountered, resulting in a prolonged treatment time (32).

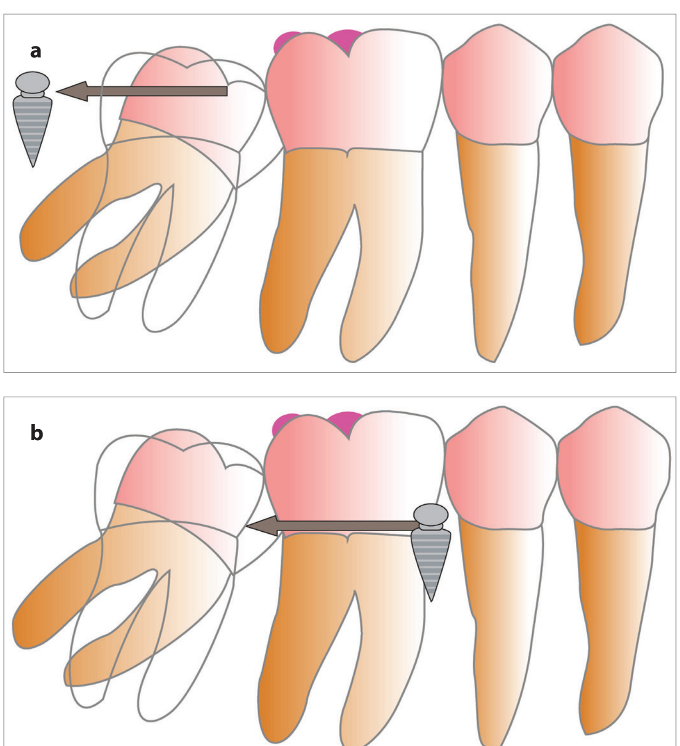

Figure 6. a, b. Molar uprighting as a result of distally directed pulling force (a). Molar uprighting as a result of pushing force (b)

With the development of skeletal anchorage, more precise force systems can be applied on target tooth, resulting in more efficient tooth movements in a shorter period of time. Lee et al. (33) used sectional mini-implant supported mechanics to upright mandibular second molars. In this method, a mini implant is placed in the mesial or distal side of the impacted tooth.

The retromolar area is frequently used as an anchorage point on the distal side of impaction. Using the retromolar area to position orthodontic implants was first proposed by Roberts et al. (34) in 1990, and using it in the method for mandibular molar uprighting was later proposed by Shellart et al. (35) in 1996. In this method, the molar is uprighted via a distalizing force, exerted through the use of elastomeric threads. The uprighting procedure generally requires a low force of 50–80 gr. The tooth is uprighted as a result of distally directed "pulling" force (33) (Figure 6a).

The retromolar area is a suitable anatomic place to position mini implants because of the compact bone that contributes the primary stability. However, the thick overlying soft tissue and poor accesibility may hinder the miniscrew insertion. The position of the mandibular canal should also be carefully examined to prevent any neurologic complications upon screw insertion (36).

In an adolescent patient with a developping third molar, it is difficult to insert a miniscrew in the retromolar area unless the third molar is extracted. In such cases, the miniscreew can be inserted on the mesial side of the tipped molar to generate a "pushing" force (Figure 6b). On the mesial side, the miniscrew is generally inserted in between the roots of the second premolar and the first molar.

The appliance design should be made according to the spesific needs of the case, such as the screw insertion site, and the force system required for uprighting. When the screw is inserted on the mesial side, the "pushing" force is exerted via an open coil spring. Miniscrews used for anchorage are typically titanium mini implants 1.8 mm in diameter and 7 mm long. The average treatment time for molar uprighting using miniscrews is reported to be 7 to 9 months (33, 36).

In the sectional-miniscrew-assisted molar uprighting method developed by Lee et al. (33), a molar tube is bonded on the molar to be uprighted. In this method, either the buccal surface of the teeth should be accessible in the mouth or the tooth should be surgically uncovered. Nienkemper et al. (37) developed an alternative method suitable for cases in which only the distal cusp of the teeth is accessible. This method avoids the need for surgical exposure of the buccal surface.

Mini implants are positioned in the inter radicular area between second premolar and the first molar. A buccal tube is than bond-

ed on the distal cusp of the impacted molar, and the slot is rotated 90 degrees so that it lies buccolingually (Figure 7. a, b).
0.018 SS archwire is bent vertically from the tube to the level of the implant, parallel to the occlusal plane, ending with a loop mesial to the mini implant. A Niti spring is than placed between the loop and mini implant to exert the pushing and uprighting necessary force (37).

In this type of treatment approach, only lateral forces are delivered to the mini implant, whereas in the previously discussed methods, axial forces are exerted on the miniscrew. It is known that axial loading is an important factor in miniscrew failure; thus, these mechanics are adventageous compared to other mini-implant-assisted uprighting mechanics (37).

Ramus Screws in Uprighting Mandibular Impacted Molars
Horizontally impacted molars are complex problems that are refractory to routine orthodontic treatment methods. An efficient treatment strategy requires the development of a strong anchorage device from extra-alveolar sites (38, 39). Roberts et al. (40) utilized osseointegrated implants as extra-alveolar temporary anchorage devices in 1990 to close edentolous spaces in the mandibular arch. Although these implants are effective and reliable, they are not effective in uprighting horizontally impacted mandibular second molars because there is no convenient space to place the osseointegrated fixture distal to the impaction site (41).

Other researchers introduced the use of titanium miniscrews in the interradicular area; however, they are not well suited for complex problems such as horizontal impaction, and they have higher failure rates, particularly in the posterior mandible (30, 42). Interradicular mini implants also are not suitable for deeply impacted molars since they cause limitations such as root damage, movement within the bone, and interference with the path of tooth movement (42).

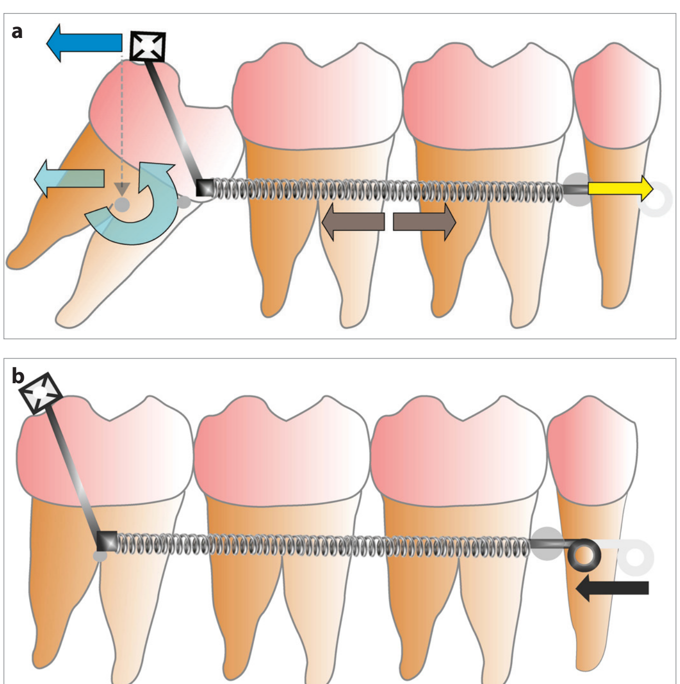

Figure 7. a, b. An alternative Molar uprighting method, designed by Nienkemper et al.

Realizing the limitations of conventional temporary anchorage devices, Chang et al. (39) expanded the skeletal anchorage concept by developing a stainless steel bone screw, 2 mm in diameter, that is suitable for extra-alveolar sites, such as the mandibular buccal shelf (MBS), zygomatic process, and mandibular ramus.

The MBS bone screws are placed laterally to the first and second molars; thus, they do not interfere with the retromolar region of impaction. However, mechanics to upright horizontally impacted molars using MBS screws are complicated and difficult to control. To be able to upright a horizontally impacted molar, bone screws are placed in the ramus of the mandible to provide a more superior and posterior direction of traction. Ramus of the mandible is a suitable place to place miniscrews owing to a thick cortical bone tissue.

Ramus screw anchorage is utilized to upright deeply and horizontally impacted second molars, and it is also used in uprighting third molars that are closed to the mandibular canal, and prior to extraction to reduce the risk of paresthesia and surgery-related complications (39).

Ortho bone screws developed by Chang et al. (39) are used in the mandibular ramus area.

Extra-alveolar screws (2 mm*12 mm) are suitable for the mandibular buccal shelf area; however, in the ramus area, a longer screw is needed because of the thick movable mucosa.

A ramus screw should penetrate a thick mucosa, as well as the inferior fibers of the temporalis muscle, and it also has to have an average of 3 mm of bone engagement. To facilitate the oral hygiene, the screw head should be about 5 mm above the soft tissue. To be able to provide the adequate bone penetration and to best fit the anatomical features of the anterior ramus region, a 2 mm*14 mm screw is used in the mandibular ramus (6, 19, 39) (Figure 8).

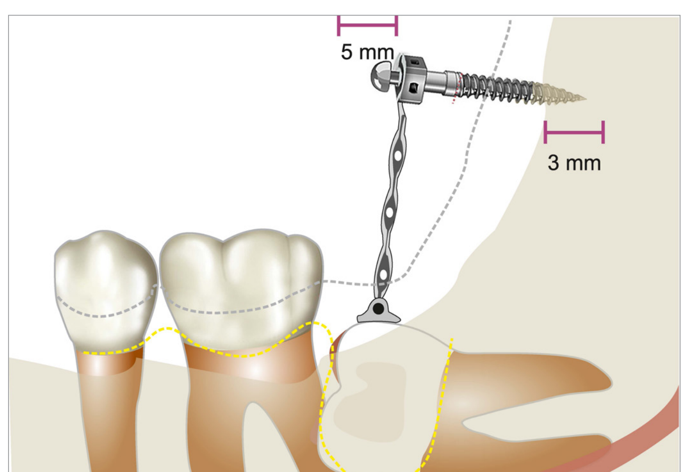

Figure 8. Ramus screw length, and appropriate insertion depth

Clinical Procedure

A full thickness flap is reflected exposing the clinical crown of the impacted molar, and bone is removed to uncover the tooth surface and establish a path of movement for uprighting. An attachment is bonded on the buccal surface of the impacted molar.

Ramus screws are installed under local anesthesia, without flap elevation or predrilling. To avoid the occlusal interferences, the optimal site to insert the screw is midway between the external and internal oblique ridges of ascending ramus, and about 5–8 mm above the occlusal plane (Figure 9). Ramus screws are loaded immediately after the insertion. Uprighting force is exerted via elastomeric chains (Power chain) stretched between the ramus screw and a button or eyelet bonded on the impacted teeth. Elastic chain is activated by one loop in every 4 weeks.

According to the study by Chang et al. (39) performed on 40 horizontally impacted molars uprighted with ramus screws, this method was found to be predictable and effective, and also, the average time for uprighting the molar was found to be maximum 4 months. At the 5th month, the previously impacted molars are bonded with a routine buccal tube.

Selecting bonding devices is as important as the screw insertion site in the molar uprighting procedures. The most popular bondable attachments for uprighting molars are buttons or eyelets. When choosing between these two options, the first concern is the line of force. Buttons are well designed for horizontal traciton, but elastics can be more easily displaced as the direction of force has a vertical orientation. The second concern should be placing and replacing the chains, and an eyelet should be bonded with the elastic attached previously, whereas buttons are more convenient if the elastic must be changed. If the attachment is bonded on an erupted surface of the tooth and the line of traction is appropriate,e buttons are convenient; however, if the attachment is bonded on an unerupted tooth surface, eyelets are safer. Also, the flat surfaces of an eyelet facilitate the manipulation when holding it with hemostat or pliers making it a more comfortable choice for impacted molars (21). Flowable composite resin can be used to secure the elastic chain on each type of attachment to prevent the detachment of the elastic chain. (19)

Potential Risks and Complications of Ramus Screws

For temporary anchorage devices in a challenging intraoral site such as the anterior ramus, the major concern are the complications and failure.

Soft Tissue Hyperthrophy

Alveolar mucosa in the anterior region of the ramus is very thick and mobile, and it is also attached to an active muscle tissue. Thus, controlling soft tissue inflamation in this area can be a challenge. Complex surgical and mechanical procedures may compromise the periodontium in areas where it is difficult to maintain oral hygiene, so periodontal health should be monitored carefully in ramus screw cases prior to, during, and after the treatment (43).

The root form and divergence are also important cosiderations relative to periodontal prognosis. Divergence of roots is preferable in terms of periodontal prognosis after uprighting compared to fusion. This is an important factor when deciding on the extraction of molars. 189

Damage to anatomical structures

The anatomical structure presenting the most serious risk for complication is the neurovascular bundle of the inferior alveolar canal. Under normal clinical conditions, the ramus screw is abot 15–20 mm away from the neurovascular bundle, and post-operative panoramic radiographs indicate that the screw tip is about 5–8 mm away from the canal after the screw insertion. Thus, if the clinical instructions upon positioning the screw are followed carefully, the risk of damaging the neurovascular bundle is minimal, except for the anatomical variations (6).

Screw Fracture or Failure

Fracture is an important risk for small-diameter screws made of a brittle material such as titanium, especially when inserted in the cortical bone (44). The risk of fracture is decreased by increasing the diameter or using a tougher material such as stainless steel. Predrilling also reduces the risk of fracture; however, because

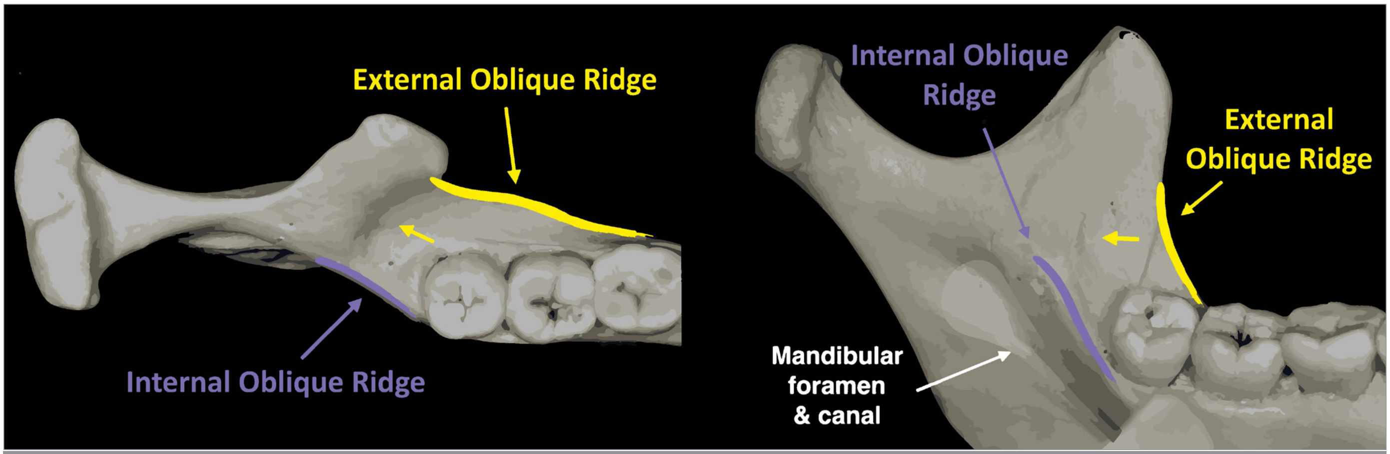

Figure 9. Positioning of mandibular Ramus Screw

of the thick and mobile mucosa in the ramus area, predrilling is not applicable for ramus screws. The risk of fracture is minimized by using stainless steel screws and increasing the diameter. Increasing the length of the screw renders it more susceptible to fracture; however, there is no case report up to date indicating fracture in a ramus screw.

The main concern should be the failure of the screw in a challenging area like the mandibular ramus (39). Based on the previous studies, the rate of failure of extra-alveolar implants is approximately the same with osseointegrated implants (less than 5%), and this rate is significantly lower compared to the failure rates of interradicular mini implants (45).

The success rates of interradicular temporary anchorage devices ranges between 57% and 95% in different studies, with a mean success rate of 84% (46). The success rate of mandibular buccal shelf screws is found to be 92.8% (47).

In the study of Chang et al. (39) in which they evaluated the success and failure rates of ramus screws on 37 patients, only two screws failed to serve as an adequate anchorage for molar uprighting. Failures occuried due to soft tissue hyperplasia related to poor oral hygiene.

CONCLUSION

Mandibular molar uprighting leads to the normalization of functional and periodontal occlusion, enabling the roots to be positioned perpendicular to the occlusal plane and resist the occlusal forces easily. Depending on the severity of inclination or impaction, there are various surgical and orthodontic treatment alternatives. With the development of miniscrews and skeletal anchorage techniques, molar uprighting is facilitated with more predictable results and less side effects. Lately, the use of extra-alveolar temporary anchorage devices, such as mandibular ramus screws, enabled the uprighting of horizontally and deeply impacted mandibular molars that were considered impossible before.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision - E.Ö., G.M.; Design - İ.T., E.Ö., G.M.; Resources - İ.T., E.Ö., G.M.; Materials - İ.T., E.Ö., G.M.;. Data Collection and/or Processing - İ.T., E.Ö., G.M.; Analysis and/or Interpretation - İ.T.,E.Ö., G.M.; Literature Search - İ.T.,E.Ö., G.M.; Writing Manuscript - İ.T., E.Ö., G.M.; Critical Review - İ.T., E.Ö., G.M.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Grover PS, Lorton L. The incidence of unerupted permanent teeth and related clinical cases. Oral Surg Oral Med Oral Pathol 1985; 59: 420-5. [CrossRef]
2. Owen, A.H.III: Early surgıcal management of impacted mandibular second molars. J Clin Orthod 1998; 32: 446-50.
3. Cho SY, Ki Y, Chu V, Chan J. Impaction of permanent mandibular second molars in ethnic Chinese schoolchildren. J Can Dent Assoc 2008; 74: 521.
4. Bishara SE, Ortho D, Burkey PS. Second molar extractions: a review. Am J Orthod 1986; 89: 415-24. [CrossRef]
5. Frank CA. Treatment options for impacted teeth. J Am Dent Assoc 2000; 131: 623-32. [CrossRef]
6. Chang CH, Lin JS, Roberts WE. Ramus screws: the ultimate solution for lower impacted molars. Semin Orthod 2018; 24: 135-54. [CrossRef]
7. Frazier-Bowers SA, Simmons D, Koehler K, Zhou J. Genetic analysis of familial non-syndromic primary failure of eruption. Orthod Craniofac Res 2009; 12: 74-81. [CrossRef]
8. Sawicka M, Racka-Pilszak B, Rosnowska-Mazurkiewicz A. Uprighting partially impacted permanent second molars. Angle Orthod 2007; 77: 148-54. [CrossRef]
9. Eckhart JE. Orthodontic uprighting of horizontally impacted mandibular second molars. J Clin Orthod 1998; 32: 621.
10. Kravitz ND. Treatment with the mandibular Arnold expander. J Clin Orthod 2014; 48: 689.
11. Proffit W, Fields H. Contemporary Orthodontics. 5th edition. Elsevier Health Sciences, 2014.
12. Kravitz ND, Yanosky M, Cope JB, Silloway K, Favagehi M. Surgical Uprighting of Lower Second Molars. J Clin Orthod 2016; 50: 33-40.
13. Ritchey B, Orban B. The crests of the interdental alveolar septa. J Period 1953; 24: 75-87. [CrossRef]
14. Shellhart WC, Oesterle LJ. Uprighting molars without extrusion. J Am Dent Assoc 1999; 130: 381-5. [CrossRef]
15. Zachrisson BU, Bantleon HP. Ask an expert: Optimal mechanics for mandibular molar uprighting. World J Orthod 2005; 6: 80-7.
16. Winter GB. Impacted mandibular third molars. St Louis: American Medical Book Co.; 1926. p. 241-79.
17. Pell GJ, Gregory BT. Impacted mandibular third molars: classification and modified techniques for removal. Dent Digest 1933; 39:330-8.
18. Huang C, Su BCW, Chang CH, Roberts WE. Asymmetric Class II Malocclusion Acquired from Early Loss of a LR6 and UL Primary Canine: Reverse the Etiology and Align a Horizontally Impacted LR8 with a Ramus Bone Screw. J Digit Orthod 2018; 50: 26-43.
19. Lin SY, Chang C, Roberts WE. Simple mechanics to upright horizontally impacted molars with ramus screws. Orthod J Nepal 2016; 5: 42-7. [CrossRef]
20. Tinerfe TJ, Blakey GH. Oral and maxillofacial surgery. Saunders, Philadelphia 2000.
21. Orton-Gibbs S, Crow V, Orton HS. Eruption of third permanent molars after the extraction of second permanent molars. Part 1: assessment of third molar position and size. Am J Orthod Dentofacial Orthop 2001; 119: 226-38. [CrossRef]
22. Lindh T. Should we extract teeth to avoid tooth-implant combinations? J Oral Rehab 2008, 35: 44-54. [CrossRef]
23. Pogrel MA. The surgical uprighting of mandibular second molars. Am J Orthod Dentofacial Orthop 1995; 108: 180-3. [CrossRef]
24. Isidor F, Karring T, Nyman S, Lindhe J. The significance of coronal growth of periodontal ligament tissue for new attachment formation. J Clin Period 1986; 13: 145-50. [CrossRef]
25. Padwa BL, Dang RR, Resnick CM. Surgical uprighting is a Successful Procedure for Management of Impacted Mandibular Second Molars. J Oral Maxillofac Surg 2017; 75: 1581-90. [CrossRef]
26. Melsen B, Fiorelli G, Bergamini A. Uprighting of lower molars. J Clin Orthod 1996; 30: 640-5.
27. Moro N, Murakami T, Tanaka T, Ohto C. Uprighting of impacted third molars using brass ligature wire. Austr Orthod J 2002; 18: 35-8.
28. Burch JG, Bagci B, Sabulski D, Landrum C. Periodontal changes in furcations resulting from orthodontic uprighting of mandibular molars. Quintescence Int 1992; 23: 509-13.

29. Raveli TB, Raveli DB, de Mathias Almeida KC, Pinto ADS. Molar uprighting: A Considerable and safe decision to avoid prosthetic treatment. Open Dent J 2017; 11: 466-75. [CrossRef]
30. Costa A, Raffainl M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthodon Orthognath Surg 1998; 13: 201-9.
31. Melo AC, Duarte da Silva R, Shimizu RH, Campos D, Andrighetto AR. Lower molar uprighting with miniscrew anchorage: direct and indirect anchorage. Int J Orthod Milwaukee 2013; 24: 9-14.
32. Magkavali-Trikka P, Emmanouilidis G, Papadopoulos MA. Mandibular molar uprighting using orthodontic miniscrew implants: a systematic review. Prog Orthod 2018; 19: 1-8. [CrossRef]
33. Lee KJ, Park YC, Hwang WS, Seong EH. Uprighting mandibular second molars with direct miniscrew anchorage. J Clin Orthod 2007; 41: 627-35.
34. Roberts WE, Marshall KJ, Mozsary PG. Rigid endosseous implant utilized as anchorage to protract molars and close an atrophic extraction site. Angle Orthod 1990; 60: 135-52.
35. Park HS, Kyung HM, Sung JH. A simple method of molar uprighting with microimplant anchorage. J Clin Orthod 2002; 36: 592-6.
36. Nęcka A, Skrzypczyński J, Antoszewska J. Miniscrew-anchorage in treatment of impacted second molar in mandible - case report. Dent Med Prob 2010; 47: 379-83.
37. Nienkemper M, Ludwig B, Kanavakis G, Pauls A, Wilmes B, Drescher D. Uprighting mesially impacted lower third molars with skeletal anchorage. J Clin Orthod 2016; 50: 420-6.
38. Lin JJ. The wisdom of managing wisdom teeth-Part III. Methods of molar uprighting. Int J Orthod Implantol 2011; 24: 4-11.
39. Chang C, Lin SY, Roberts WE. Forty consecutive ramus bone screws used to correct horizontally impacted mandibular molars. Int J Orthod Implantol 2016; 41: 60-72.
40. Roberts WE. Rigid implant anchorage to close a mandibular first molar extraction site. J Clin Orthod 1994; 28: 693-704.
41. Kanomi R. Mini implant for orthodontic anchorage. J Clin Orthod 1997; 31: 763-7.
42. Liou EJ, Pai BC, Lin JC. Do miniscrews remain stationary under orthodontic forces? Am J Orthod Dentofacial Orthop 2004; 126: 42-7. [CrossRef]
43. Lim HJ, Eun CS, Cho JH, Lee KH, Hwang HS. Factors associated with initial stability of miniscrews for orthodontic treatment. Am J Orthod Dentofacial Orthop 2009; 136: 236-42. [CrossRef]
44. Lin JJ. 2 mm bone screw vs MIA. Int J Ortho Implantol 2008; 9: 1-5.
45. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2003; 124: 373-8. [CrossRef]
46. Viwattanatipa N, Thanakitcharu S, Uttraravichien A, Pitiphat W. Survival analyses of surgical miniscrews as orthodontic anchorage. Am J Orthod Dentofacial Orthop 2009; 136: 29-36. [CrossRef]
47. Chang C, Liu SS, Roberts WE. Primary failure rate for 1680 extra-alveolar mandibular buccal shelf mini screws placed in movable mucosa or attached gingiva. Angle Orthod 2015; 85: 905-10. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.20034

Case Report

Correction of Unilateral Posterior Crossbite with U-MARPE

Jonathan Dzingle[1], Shivam Mehta[2], Po-Jung Chen[2], Sumit Yadav [2]

[1]Private Practice, Michigan, United States
[2]Division of Orthodontics, University of Connecticut Health Center, School of Dental Medicine, Farmington, Connecticut, United States

Cite this article as: Dzingle J, Mehta S, Chen PJ, Yadav S. Correction of Unilateral Posterior Crossbite with U-MARPE. Turk J Orthod 2020; 33(3): 192-6.

ABSTRACT

Unilateral posterior crossbite typically presents as a narrow maxillary arch and a broad mandibular arch on the side of the crossbite. Unwanted overexpansion and iatrogenic crossbite may develop as side effects if conventional rapid maxillary expansion is done in such cases. Thus, unilateral expansion of the maxilla with unilateral posterior crossbite can help us avoid these side effects and improve the transverse relationship between the maxillary and mandibular posterior dentition on the affected side only. In this case report, we describe a mini-implant–supported unilateral expansion of the maxillary arch in a patient with a unilateral posterior crossbite.

Keywords: Asymmetry, mini-implant, unilateral crossbite, unilateral expansion

Main points:

- Unilateral posterior crossbite can be corrected with a modified design of mini-implant–assisted rapid palatal expander (MARPE)—the U-MARPE—without undesirable movement on the unaffected side.
- U-MARPE facilitates better control over force distribution than a regular expander and thus more efficient correction of the unilateral posterior crossbite.
- Comprehensive diagnosis and treatment planning can lead to targeted orthodontic mechanotherapy and esthetic results.

INTRODUCTION

Unilateral posterior crossbite is usually characterized by a narrow maxillary arch and broad mandibular arch on the crossbite side (1). These patients are treated with maxillary expansion to correct the transverse discrepancy, but ideally, the expansion should be done only for the side that is in crossbite (2). A posterior crossbite is a form of discrepancy in the transverse dimension between the maxillary and mandibular arches with a prevalence of 8%–23% (3). Both unilateral and bilateral posterior crossbite are equally prevalent (4-6). The etiology is multifactorial, which influences dentofacial growth and may lead to the development of posterior crossbite (5).

The treatment of posterior crossbite often involves maxillary arch expansion to improve the relationship between the maxillary arch and mandibular arch in the transverse dimension. However, when bilateral rapid palatal expansion (RPE) is done in a patient with unilateral posterior crossbite, it results in overexpansion and iatrogenic creation of the crossbite on the side that had normal transverse relationship before treatment (7, 8). In addition, the treatment of iatrogenic crossbite results in increased treatment time and increased discomfort for the patient. Thus, unilateral expansion of the maxilla in patients with unilateral posterior crossbite can help us avoid these side effects and can be used to correct the transverse relationship between the maxillary and mandibular posterior dentition on the affected side only. In this case report, we describe a modified mini-implant–assisted rapid palatal expander (MARPE) design for unilateral expansion (U-MARPE) of the maxillary arch in order to correct the unilateral posterior crossbite.

Address for Correspondence: Sumit Yadav, Division of Orthodontics, University of Connecticut Health Center, School of Dental medicine, Farmington, Connecticut, United States
E-mail: syadav@uchc.edu

Received: April 6, 2020
Accepted: May 18, 2020
Available Online Date: July 20, 2020

CASE PRESENTATION

Diagnosis

A 19-year-old Hispanic male presented to the department of Orthodontics with the chief complaint that he was not pleased with his bite. The patient reported food allergy; however, no contraindication to orthodontic treatment was noted. Clinical examination showed a straight profile (Figure 1). Maxillary dental midline and facial midline were coincident, and there was deviation of the mandibular dental midline to the left by 1 mm. He had Class III canine and Class I molar relationship bilaterally (Figure 1). The teeth from the maxillary left canine to the maxillary left second molar were in a crossbite, and no discrepancy was noted between centric occlusion and centric relation. Crowding of 2 mm and 1.5 mm in the maxillary arch and the mandibular arch, respectively, was noted. There were no signs or symptoms of temporomandibular joint dysfunction. No significant pathology was found in the panoramic radiograph (Figure 2). The lateral cephalogram showed a Class I maxillomandibular relationship with Class III tendency and normal mandibular plane angle (Figure 3). In summary, the patient was diagnosed with skeletal and dental Class I malocclusion.

Treatment Objectives

The treatment objectives were to (1) achieve Class I canine relationship and maintain Class I molar relationship bilaterally, (2) establish a normal buccal overjet and overbite relationship, and (3) maintain the facial profile.

Figure 1. Pretreatment facial and intraoral photographs

Figure 2. Pretreatment panoramic radiograph

Treatment Plan and Alternatives

Different treatment plans were taken into consideration and explained to the patient. The treatment plan chosen for this patient was non-extraction and non-surgical treatment with U-MARPE for maxillary expansion to correct the posterior crossbite. After discussing this option with the patient, a non-extraction treatment with U-MARPE was adopted.

Another treatment option was non-extraction orthodontic treatment combined with surgically assisted rapid maxillary expansion (SARME). This approach can correct the transverse skeletal discrepancy; however, the patient did not accept this plan because of the added financial burden, having to undergo a surgical procedure, and the complications.

Treatment Progress

The different treatment options and the objectives of the orthodontic treatment were described to the patient in detail, and the written informed consent form was obtained. The U-MARPE appliance was delivered with 2 mini-implants (2×8 mm, 3M Unitek, St. Paul, MN) on the right palatine bone and bands on maxillary left first molar and first premolar (Figure 4). The activation was started with one turn per day for 2 weeks. The crossbite on the left side was corrected after expansion. The expander was stabilized for 5 months after expansion.

Figure 3. Pretreatment lateral cephalometric radiograph

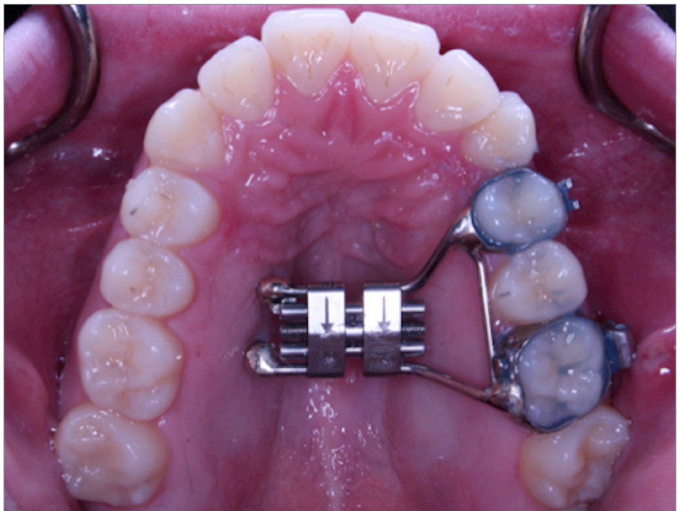

Figure 4. U-MARPE appliance applied with 2 mini-implants and bands on the maxillary first premolar and maxillary first molar

Figure 5. Removed U-MARPE and the bonded pre-adjusted edgewise appliance 0.022×0.028.

Figure 6. Posttreatment facial and intraoral photographs

The U-MARPE was removed after 6 months of stabilization. Bonding was done using the preadjusted edgewise appliance with 0.022×0.028-in slot size (Figure 5). The leveling and alignment was achieved by beginning with 0.016-in nickel-titanium and building up to 0.019×0.025-in stainless steel in 6 months.

Braided stainless steel archwires (0.017×0.025-in) were used for finishing. The orthodontic treatment was completed in 24 months. For retention, upper Essix clear retainer and lower lingual fixed retainer were used.

Figure 7. Posttreatment panoramic radiograph

Figure 8. Posttreatment lateral cephalometric radiograph

Treatment Results

The patient was very satisfied with the treatment result and exhibited a pleasant smile at the end of treatment (Figure 6). The palatal crossbite was corrected, and the arches were well aligned with ideal overbite and overjet. The dental midlines were coincident in both arches.

Good root parallelism was observed after treatment (Figure 7). The overall superimposition showed mild mandibular growth, whereas regional superimposition showed mild extrusion of mandibular incisors and mandibular first molars (Figures 8 and 9). The occlusogram showed the asymmetric expansion of the maxillary arch (Figure 10).

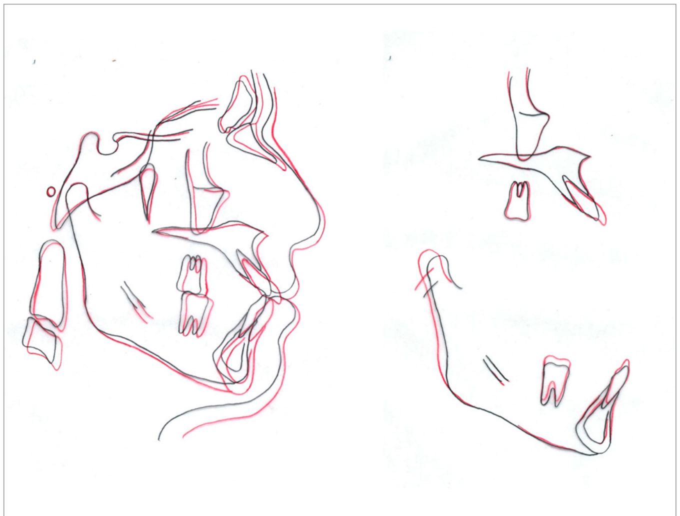

Figure 9. Superimposition showing pretreatment (black) and posttreatment (red) cephalograms

Figure 10. Superimposition of the pretreatment (blue) and posttreatment (orange) maxillary arch occlusograms

DISCUSSION

In a true unilateral posterior crossbite, it is very important that the appliance design and load system are such that unilateral expansion occurs only on the affected side and not on the side without crossbite. In our patient, U-MARPE was used to correct unilateral crossbite without undesirable movement on the unaffected side. The occlusion of the side without crossbite was maintained very well after the expansion was done. Instead of using conventional RPE and Surgically Assisted Rapid Palatal Expansion (SARPE), the U-MARPE demonstrated a decent amount of expansion without additional surgery in a 19-year-old patient.

The objective of the U-MARPE was to allow expansion of the crossbite side without clinical side effects on the opposite side. Use of the conventional RPE procedure to correct unilateral posterior crossbite needs an asymmetric relapse after bilateral expansion. To avoid this undesirable movement, previous studies support the use of an RPE with an acrylic plate having locked mechanics on the side without crossbite to produce asymmetric orthopedic and orthodontic effects (2, 9). Appliances such as an asymmetric maxillary expansion (AMEX) appliance have also been used for the correction of unilateral crossbite (10). It has been reported to show increased expansion on the crossbite side and relatively less expansion on the side without crossbite. However, the activation of the appliance is done extra-orally, which requires removal and recementation of the appliance and, thus, increase the clinical chair time. In addition, some side effects might be observed on the maxillary and mandibular premolars and molars on the side without crossbite because they are used as anchorage units. In our design, the activation of the screw was done intraorally by the patient and does not use mandibular teeth as an anchor unit and therefore does not lead to expansion of the mandibular teeth. However, the results of the AMEX appliance imply that it can be used as an alternative in patients who do not wish to use temporary anchorage devices (TADs) (10).

As unilateral expansion has been reported with SARME in adults, it was an alternative treatment plan for our patient (11). The results from the study by Karabiber et al. (11) showed that there was more expansion on the osteotomy side with unilateral SARME, which helped in the correction of the transverse discrepancy. Thus, unilateral SARME is an effective technique for the correction of unilateral crossbite. However, they found that there were no significant skeletal changes except for apertura piriformis (11). In addition, the SARME technique requires the patient to undergo surgery under general anesthesia and adds supplementary financial cost to the treatment. Complications like epistaxis, postoperative pain, asymmetric expansion, or inadequate expansion have been reported with SARME (12). Unilateral expansion with the U-MARPE design enabled us to correct the transverse discrepancy without surgery. The design of the U-MARPE appliance was such that the expansion force was felt by the TADs on the side without crossbite (right side) and the molars and premolars on the crossbite side (left side). This design provided better control over the force distribution than a regular expander. This enabled us to expand the molars and premolars on the left side without affecting the right side and get results comparable to those shown by unilateral SARME (11).

In the U-MARPE design, we used 2 palatal implants on the side without crossbite, and the appliance was cemented on the TADs. One advantage of using palatal TADs is their high success rate (13). The advantage of U-MARPE is that it can be delivered in the clinic under local anesthesia. Previous studies have reviewed that the results obtained with MARPE are stable (14, 15). A clinical study stated that MARPE is a stable treatment option for expansion of maxillary arch and showed that suture separation was achieved in 86.96% of those patients (15). However, this is a modified MARPE design, and further research should be done to evaluate the skeletal and dental effects of the U-MARPE design.

During expansion with the MARPE appliance, the TADs on both the sides of the mid-palatal suture apply force from the expansion screw through the palatal bone on either side of the suture, leading to the opening of the mid-palatal suture. However, in the U-MARPE design, the TADs are inserted on only one side of the mid-palatal suture, and thus, the effects could be different than MARPE. Achieving a pure skeletal expansion was not the aim in this case, as U-MARPE will lead to expansion on both sides of the maxilla and side effects of creating a crossbite on the normal side. Rather, the objective of the U-MARPE design was to get clinical correction of the crossbite efficiently without expansion on the normal side. We believe the result obtained in our case was a combination of skeletal and dental expansion on the crossbite side. However, we did not record an occlusal radiograph of the patient after expansion in order to prevent additional radiation. However, further studies with radiographs before and after U-MARPE may help in understanding the amount of dental and skeletal expansion achieved with U-MARPE.

Thus, in this case report, we showed a case with modified MARPE design, U-MARPE, for the efficient correction of unilateral crossbite.

CONCLUSION

This case demonstrates that the use of MARPE is an effective approach to correct unilateral crossbite without causing side effects and undesirable movement on the side without crossbite.

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – J.D., S.M., P.J.C., S.Y.; Design – J.D., S.M., P.J.C., S.Y.; Supervision – J.D., S.M., P.J.C., S.Y.; Resources – J.D., S.M., P.J.C., S.Y.; Materials – J.D., S.M., P.J.C., S.Y.; Data Collection and/or Processing – J.D., S.M., P.J.C., S.Y.; Analysis and/or Interpretation – J.D., S.M., P.J.C., S.Y.; Literature Search – J.D., S.M., P.J.C., S.Y.; Writing Manuscript – J.D., S.M., P.J.C., S.Y.; Critical Review – J.D., S.M., P.J.C., S.Y.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Thilander B, Lennartsson B. A study of children with unilateral posterior crossbite, treated and untreated, in the deciduous dentition--occlusal and skeletal characteristics of significance in predicting the long-term outcome. J Orofac Orthop 2002; 63: 371-83. [Crossref]
2. Marshall SD, Southard KA, Southard TE. Early transverse treatment. Semin Orthod 2005; 11: 130-39. [Crossref]
3. Kutin G, Hawes RR. Posterior cross-bites in the deciduous and mixed dentitions. Am J Orthod 1969; 56: 491-504. [Crossref]
4. Thilander B, Myrberg N. The prevalence of malocclusion in Swedish schoolchildren. Scand J Dent Res 1973; 81: 12-21. [Crossref]
5. Dimberg L, Lennartsson B, Arnrup K, Bondemark L. Prevalence and change of malocclusions from primary to early permanent dentition: a longitudinal study. Angle Orthod 2015; 85: 728-34. [Crossref]
6. Fontaine-Sylvestre C, Roy A, Rizkallah J, Dabbagh B, Ferraz Dos Santos B. Prevalence of malocclusion in Canadian children with autism spectrum disorder. Am J Orthod Dentofacial Orthop 2017; 152: 38-41. [Crossref]
7. Thilander B, Lennartsson B. A study of children with unilateral posterior crossbite, treated and untreated, in the deciduous dentition--occlusal and skeletal characteristics of significance in predicting the long-term outcome. J Orofac Orthop 2002; 63: 371-83. [Crossref]
8. Agostino P, Ugolini A, Signori A, Silvestrini-Biavati A, Harrison JE, Riley P. Orthodontic treatment for posterior crossbites. Cochrane Database Syst Rev 2014; 8: CD000979. [Crossref]
9. Ileri Z, Basciftci FA. Asymmetric rapid maxillary expansion in true unilateral crossbite malocclusion: A prospective controlled clinical study. Angle Orthod 2015; 85: 245-52. [Crossref]
10. Toroglu MS, Uzel E, Kayalioglu M, Uzel I. Asymmetric maxillary expansion (AMEX) appliance for treatment of true unilateral posterior crossbite. Am J Orthod Dentofacial Orthop 2002; 122: 164-73. [Crossref]
11. Karabiber G, Yılmaz HN, Nevzatoğlu Ş, Uğurlu F, Akdoğan T. Three-dimensional evaluation of surgically assisted asymmetric rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2019; 155: 620-31. [Crossref]
12. Carvalho PHA, Moura LB, Trento GS, Holzinger D, Gabrielli MAC, Gabrielli MFR, et al. Surgically assisted rapid maxillary expansion: A systematic review of complications. Int J Oral Maxillofac Surg 2020; 49: 325-32. [Crossref]
13. Crismani AG, Bernhart T, Schwarz K, Celar AG, Bantleon HP, Watzek G. Ninety percent success in palatal implants loaded 1 week after placement: a clinical evaluation by resonance frequency analysis. Clin Oral Implants Res 2006; 17: 445-50. [Crossref]
14. Lim HM, Park YC, Lee KJ, Kim KH, Choi YJ. Stability of dental, alveolar, and skeletal changes after miniscrew-assisted rapid palatal expansion. Korean J Orthod 2017; 47: 313-22. [Crossref]
15. Choi SH, Shi KK, Cha JY, Park YC, Lee KJ. Nonsurgical miniscrew-assisted rapid maxillary expansion results in acceptable stability in young adults. Angle Orthod 2016; 86: 713-20 [Crossref]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.20064

Expert Opinion

Efficient Distalization of Maxillary Molars with Temporary Anchorage Devices for the Treatment of Class II Malocclusion

Moschos A. Papadopoulos

Department of Orthodontics, Faculty of Dentistry, School of Health Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece

Cite this article as: Papadopoulos MA. Efficient Distalization of Maxillary Molars with Temporary Anchorage Devices for the Treatment of Class II Malocclusion. Turk J Orthod 2020; 33(3): 197-201.

Main points:

- Orthodontic treatment of patients with Class II malocclusion by means of maxillary molar distalization can be very challenging.
- Orthodontic miniscrew implants can be used as temporary anchorage devices (TADs) to enhance the anchorage and, if properly used, to counterbalance the side effects of conventional or noncompliant distalization approaches.
- The TAD-supported amda® can be considered as a simple, noncompliant, minimally invasive, and very efficient approach that can be used for the comprehensive treatment of patients with Class II malocclusion.

ABSTRACT

Treatment of Class II malocclusion often requires maxillary molar distalization. However, when applying distalization forces on the maxillary molars, anchorage loss may occur in different degrees not only during molar distalization (such as distal tipping of maxillary molars and mesial movement and proclination of the anterior teeth) but also during the subsequent stage of anterior teeth retraction (such as mesial movement of maxillary molars). All these movements are considered as unwanted side effects, which diminish the clinical effectiveness of distalization. Miniscrew implants can be used as temporary anchorage devices (TADs) to enhance anchorage and, if properly used, to counterbalance the side effects. Among the different available systems, the TAD-supported amda® can be considered as a simple, noncompliant, minimally invasive, and very efficient approach that can be used for the comprehensive treatment of patients with Class II malocclusion not only to distalize the maxillary molars bodily without or with minimal distal tipping and without proclination of the anterior teeth but also in combination with full-fixed appliances to retract and intrude the anterior teeth.

Keywords: Class II malocclusion, molar distalization, orthodontic anchorage techniques, orthodontic tooth movement, temporary anchorage devices

INTRODUCTION

When applying distalization forces on the maxillary molars, anchorage loss may occur in different degrees during not only molar distalization but the subsequent stage of anterior teeth retraction as well (1).

First, during maxillary molar distalization, anchorage loss can take place in the posterior or anterior area. Posterior anchorage loss includes distal tipping and/or distal rotation of the molars, which mainly depend on the biomechanics of the distalization system used (i.e., point of force application and force level and location of the center of resistance of the molars, which is considered to be at or very close to the trifurcation of their roots) (1-3). Anterior anchorage loss occurs as mesial movement and tipping of the canines and the first and/or second premolars, as well as proclination of the incisors and increase of the overjet.

Second, during the subsequent anterior teeth retraction that follows molar distalization, anchorage loss usually takes place in terms of mesial movement (and mesial tipping) of the maxillary molars because these teeth are used as anchor units at this stage of treatment (1).

Address for Correspondence: Moschos A. Papadopoulos, Department of Orthodontics, Faculty of Dentistry, School of Health Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece
E-mail: mikepap@dent.auth.gr

Received: May 21, 2020
Accepted: June 19, 2020
Available Online Date: August 20, 2020

For the moment, the only approaches that are not associated with anchorage loss during distalization involve the extraoral use of headgears or the intraoral use of skeletal or temporary anchorage devices (TADs) (4).

With regard to headgear treatment, it has to be noted that this approach requires maximum patient's cooperation, while it usually produces an orthopedic effect in terms of maxillary growth inhibition, which is not always desirable; therefore, most of the times, it cannot be utilized as part of our usual treatment plans.

In contrast, orthodontic TADs can be used for maxillary molar distalization, including all kinds of orthodontic (palatal) implants, orthodontic miniplates, or orthodontic miniscrew implants.

Previous attempts to distalize the maxillary molars using these measures with different distalization approaches have already been reported in the orthodontic literature; however, these are associated with various shortcomings.

For example, the modified Keles Slider has been used in conjunction with a single orthodontic implant positioned initially in the midpalatal suture of the palate and later in the paramedian area (5). Owing to the use of orthodontic implants instead of miniscrew implants, this approach is associated with more complicated and invasive procedures for the insertion and removal of the implant. Moreover, it needs more special, precise, and time-consuming laboratory work to connect the implant initially to the premolars (during molar distalization) and later to the molars (after molar distalization has been accomplished and during the stage of anterior teeth retraction).

Another example constitutes the use of the miniscrew-implant-supported distal jet, which is associated with the following problems: (a) a large acrylic button is still used, as with the conventional type of the appliance without miniscrews, which is usually related to hygiene problems and presence of inflammation of the underlying soft tissues; (b) the TADs are inserted between the roots of the first and second premolars or between the second premolars and first molars, a fact that is associated with a risk of root injuries of these teeth not only while inserting the implants but also during drifting of the premolars distally; and (c) to use the same appliance for the subsequent anterior teeth retraction, the TADs have to be removed and new TADs have to be inserted in different locations to facilitate the further use of the distal jet for this purpose. This procedure is time consuming and is associated with additional stress and costs for the patient (6).

Furthermore, the Beneslider (7), a distalization system also supported by miniscrew implant anchorage, presents the shortcoming that two TADs are inserted in the midpalatal suture of the palate. However, it is already known that there is still connective tissue in the midpalatal suture even in the adults and that the suture is not following a straight line (8, 9). Thus, the contact surface between the thread of the TADs and the bone is significantly decreased. Because the anchorage and thus the stability of the miniscrew implants succeed only because of mechanical retention and not through osseointegration, the decreased bone-to-implant interface may lead to a significant increase of the risk of mobility or even to the failure of the TADs. Furthermore, since both TADs are inserted in the midpalatal suture, the distal TAD is inserted in an area with decreased bone height; apart from the significant increase in the risk for immobility, most likely, it perforates or penetrates the lower border of the sinus. Finally, the length of the two Benetubes (that connect the palatal arch wire with the molar bands and transfer the distalization force to the molars) cannot be individually adjusted. Therefore, when distalizing maxillary molars with large roots, the line of action of the force system may lie more occlusally to their center of rotation, and this can lead to distal tipping of these teeth during distalization.

Another noncompliant distalization appliance that has been supported with miniscrew implant anchorage is the "bone-anchored Pendulum appliance" (10). This appliance also presents some significant problems and shortcomings: (a) similar to the TAD-supported distal jet, a large acrylic button is also still used as with the conventional type of the appliance without TADs, which usually leads to hygiene problems and inflammation of the underlying soft tissues, which in turn, may cause mobility and failure of the TADs; (b) the point of force application is located on the crown level of the maxillary molars; thus, distal tipping in different degrees of the molars usually takes place; (c) the maxillary molars are moving on a "pendulum arc" while distalizing; therefore, distal rotation of the molars always occurs, while the maxillary arch is usually significantly constricted posteriorly; (d) there is no auxiliary or any stop to prevent the movement of distalization of the molars; hence, the molars may be significantly overcorrected; in some cases, if the patient misses some appointments for any reason, the molars may end up close to the midpalatal suture.

Finally, orthodontic miniplates or miniscrew implants (that are positioned in the posterior area) can be used in conjunction with fixed appliances (braces) to distalize the maxillary molars. This is usually done in an indirect manner, i.e., by means of open-coil springs that are compressed between the maxillary molars and premolars or canines, while the premolars or canines are connected to the TADs. In these cases, because the point of force application and the level of the distalization force always lie on the crown level (i.e., below the center of resistance of the maxillary molars), distal tipping (posterior anchorage loss) always takes place.

The author of this article has recently developed a device, the miniscrew-implant-supported advanced molar distalization appliance (amda®; Dentaurum, Ispringen, Germany) (Figures 1 and 2), which constitutes a novel technique that eliminates the aforementioned drawbacks and side effects of the conventional and noncompliant distalization appliances, i.e., the anchorage loss of the anterior dental unit (in terms of mesial movement of the premolars and canines and proclination of the incisors) and of the posterior dental unit (in terms of distal tipping and rotation of the molars) during maxillary molar distalization (Figure 3a), as well as the anchorage loss of the posterior dental unit (in terms of mesial movement of the molars that have been previously distalized) during anterior teeth retraction (Figure 3b). During molar distalization with amda®, the molars are distalized almost bodily, while the appliance remains invisible (11, 12). Thereafter, the same appliance after a small chairside intraoral modification can provide the necessary anchorage for the subsequent anterior teeth retraction, which is performed in conjunction with the conventional fixed appliances.

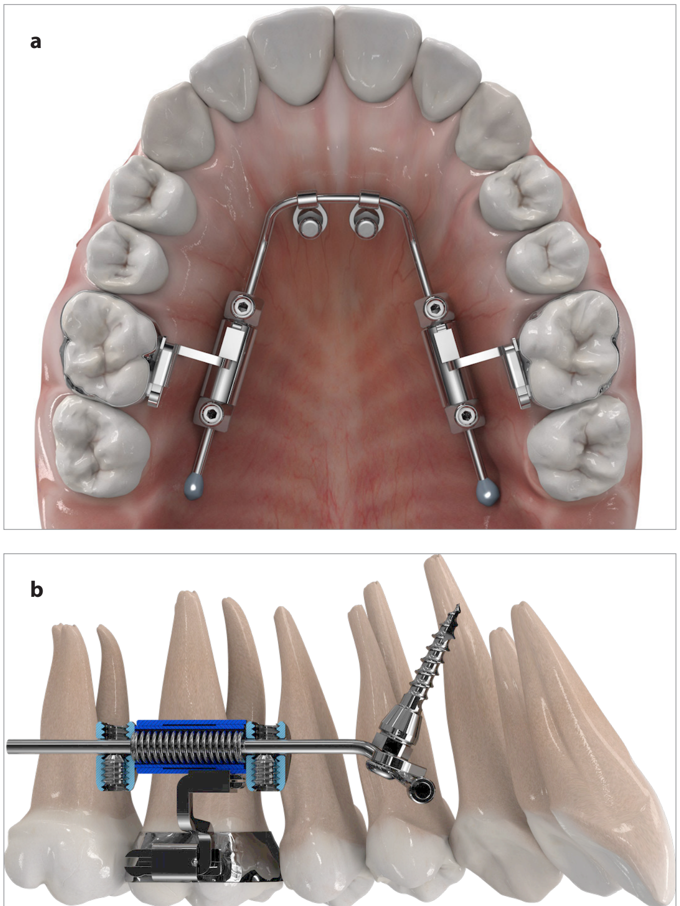

Figure 1. a, b. Three-dimensional virtual representation of the amda® (a) Occlusal view, (b) Sagittal view

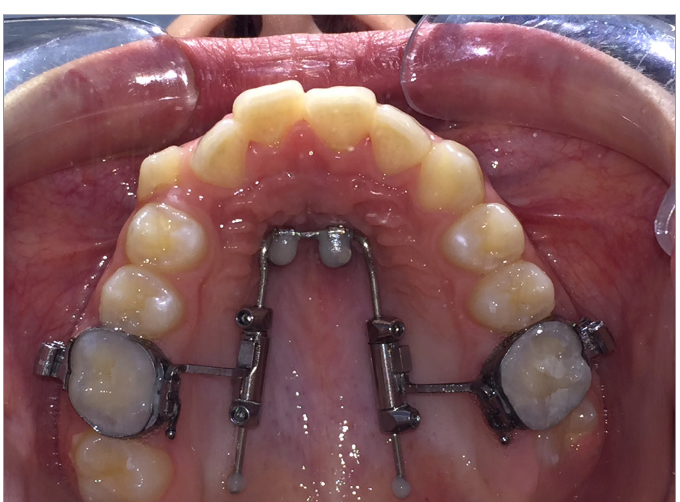

Figure 2. Occlusal view of the palate after insertion of the two tomas®-pins EP and final placement of the amda®

The amda® consists of an active and an anchorage unit. The active unit bilaterally uses an apically positioned wire-tubing system, including the active element of amda®, i.e., compressed nickel–titanium open-coil springs, which provide the necessary force for molar distalization (Figure 1b).

The anchorage unit consists of two self-drilling miniscrew implants, the tomas®-pins EP (Dentaurum, Ispringen, Germany), with which the skeletal anchorage of amda® is fulfilled. Two TADs are always used to skeletally anchor the amda® to (a) avoid possible rotational movements of the appliance in case of asymmetrical force application (e.g., for bilateral molar distalization of different amount between right and left sides or unilateral distalization) and (b) enhance the stability of the appliance. The TADs are inserted paramedian in the anterior region of the palate, especially 6–9 mm posterior to the incisive foramen and 3–6 mm paramedian because it was found that this site offers the highest amount of bone support (Figures 1 and 2) (13).

Further details regarding the clinical application of amda® have been described in the literature (4, 14). Initial treatment results highly support this new approach since the TAD-supported amda® can be used efficiently to not only distalize the maxillary molars bodily but also subsequently retract the anterior teeth without relying on patients' cooperation, in other words, for the comprehensive management of Class II malocclusion (Figure 4).

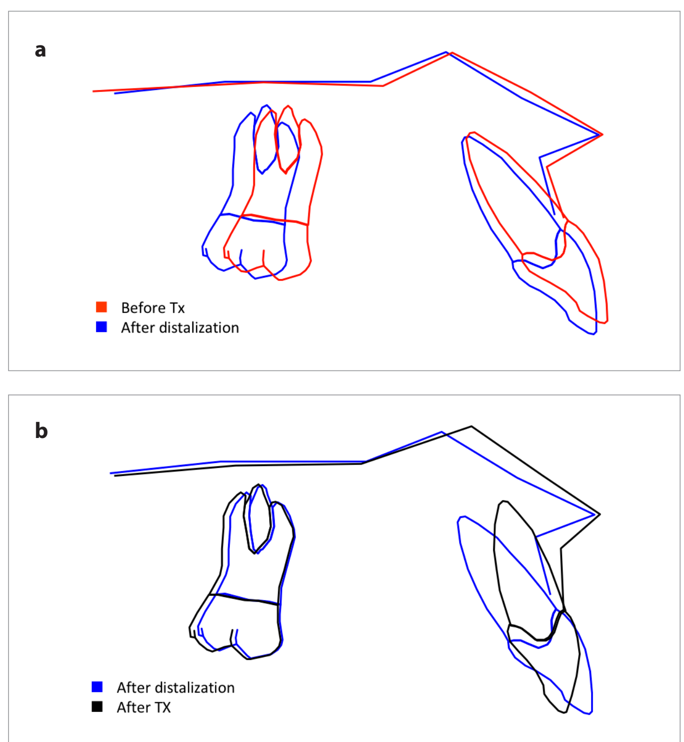

Figure 3. a, b. Superimpositions of the lateral cephalometric tracings on the maxillary plane of a patient with Class II malocclusion treated with the amda®: (a) Before and after distalization of the maxillary molars; (b) After distalization of the maxillary molars and after retraction of the anterior teeth

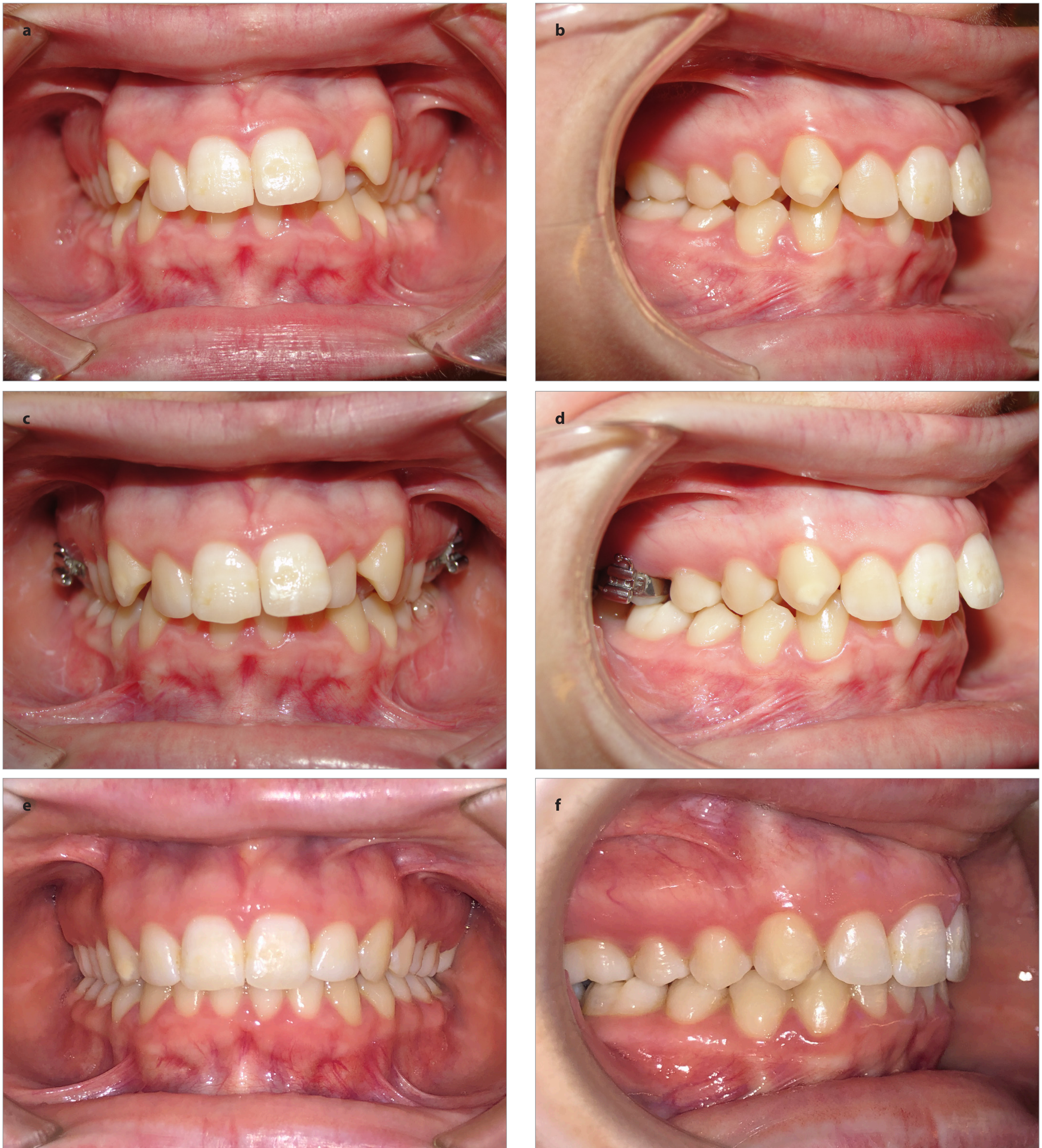

Figure 4. a-f. Intraoral photographs of a 13-year-old female with Class II malocclusion Treated with the amda®: (a, b) Before initiation of treatment; (c, d) Immediately after completion of distalization of the maxillary molars with the amda®; (e, f) Immediately after completion of treatment and after debonding of the maxillary and mandibular dental arch

As mentioned above, the amda® uses two TADs as stationary anchorage to resist the mesial-directed reciprocal forces produced by the coil springs during molar distalization, as well as later to support the subsequent anterior teeth retraction. This way, the side effects of anchorage loss of the anterior dental unit during molar distalization and that of the posterior dental unit during the subsequent anterior teeth retraction are eliminated or at least substantially minimized.

In addition, the point of force application exerted by the palatally positioned nickel–titanium open-coil springs encased in the tubing system of the amda® telescopes passes almost through or very close to the center of resistance of the maxillary molars (at the roots' trifurcation). Thus, an almost pure bodily molar distal movement is produced, while a distal molar crown tipping is avoided.

Furthermore, because the molars are forced to slide on the amda®-palatal arch and are guided through the amda® telescopes, which are all palatally positioned and run parallel to the maxillary occlusal plane, no or minimal rotation of these teeth is usually observed during distalization. However, if any molar rotation occurs, the amda® connectors can be bend with antirotation accordingly during the course of treatment to counteract this side effect.

Finally, during the subsequent stage of the retraction of the anterior teeth, posterior anchorage of the first maxillary molars is efficiently supported by the same appliance after a small and easy chairside intraoral adjustment of the amda® telescopes; thus, no mesial movement of the maxillary molars that have been just distalized is observed.

The amda® can also be very efficiently applied unilaterally in Class II subdivision cases requiring unilateral distalization only of one maxillary molar in one side or in asymmetrical Class II cases where asymmetrical distalization of the maxillary molars between right and left sides is indicated.

Although the amda® has been primarily developed for distalization of the maxillary first molars, this approach may also be utilized efficiently for the bilateral or unilateral mesialization of the maxillary molars or to distalize the first molar on one side of the maxilla and mesialize the first molar on the contralateral side.

CONCLUSION

Among the different available systems, the TAD-supported amda® can be considered as a simple, noncompliant, minimally invasive, and very efficient approach that can be used for the comprehensive treatment of patients with Class II malocclusion not only to distalize the maxillary molars bodily without or with minimal distal tipping and without proclination of the anterior teeth but also in combination with full-fixed appliances to retract and intrude the anterior teeth.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – M.A.P.; Design – M.A.P.; Supervision – M.A.P.; Resources – M.A.P.; Materials – M.A.P.; Data Collection and/or Processing – M.A.P.; Analysis and/or Interpretation – M.A.P.; Literature Search – M.A.P.; Writing Manuscript – M.A.P.; Critical Review – M.A.P.

Conflict of Interest: The author owns a US and a German patent of the amda®.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Papadopoulos MA, editor. Orthodontic treatment for the Class II non-compliant patient: Current principles and techniques. Elsevier, Mosby, Edinburgh, 2006.
2. Papadopoulos MA, Mavropoulos A, Karamouzos A. Cephalometric changes following simultaneous first and second maxillary molar distalization using a non-compliance intraoral appliance. J Orofac Orthop 2004; 65:123-36. [Crossref]
3. Mavropoulos A, Karamouzos A, Kiliaridis S, Papadopoulos MA. Efficiency of non-compliance simultaneous first and second upper molar distalization: A 3D tooth movement analysis. Angle Orthod 2005; 75: 532-9.
4. Papadopoulos MA, Tarawneh F. The use of miniscrew implants for temporary skeletal anchorage in orthodontics: a comprehensive review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 103: e6-15. [Crossref]
5. Keles A, Erverdi N, Sezen S. Bodily distalization of molars with absolute anchorage. Angle Orthod 2003; 73: 471-82.
6. Bowman SJ. The evolution of the Horseshoe Jet. In: Papadopoulos MA, editor. Skeletal anchorage in orthodontic treatment of Class II malocclusion: Contemporary applications of orthodontic implants, mini-screw implants and mini plates. Edinburgh: Elsevier, Mosby, 2015; 168-70. [Crossref]
7. Wilmes B. The Beneslider and Pendulum B appliances. In: Papadopoulos MA, editor. Skeletal anchorage in orthodontic treatment of Class II malocclusion: Contemporary applications of orthodontic implants, mini-screw implants and mini plates. Edinburgh: Elsevier, Mosby, 2015; 174: 1-7. [Crossref]
8. Melsen B. A histologic study of the influence of sutural morphology and skeletal maturation on rapid palatal expansion in children. Tram Eur Orthod Sot 1972; 499-507.
9. Melsen B. Palatal growth study on human autopsy material: A histologic microradiographic study. Am J Orthod 1975; 68: 42-54. [Crossref]
10. Kircelli HB, Pektas ZO. The bone-anchored Pendulum appliance. In: Papadopoulos MA, editor. Skeletal anchorage in orthodontic treatment of Class II malocclusion: Contemporary applications of orthodontic implants, mini-screw implants and mini plates. Edinburgh: Elsevier, Mosby, 2015: 186-8. [Crossref]
11. Papadopoulos MA, editor. Skeletal anchorage in orthodontic treatment of Class II malocclusion: Contemporary applications of orthodontic implants, mini-screw implants and mini plates. Edinburgh: Elsevier, Mosby, 2015. [Crossref]
12. Papadopoulos MA. The advanced molar distalization applicance: A novel approach to corect Class II Malocclusion. Recent Patents on Biomedical Engineering 2010; 3: 6-15. [Crossref]
13. Bernhart T, Vollgruber A, Gahleitner A, Dörtbudak O, Haas R. Alternative to the median region of the palate for placement of an orthodontic implant. Clin Oral Implants Res 2000; 11: 595-601. [Crossref]
14. Papadopoulos MA. Effective treatment of Class II malocclusion with the mini-screw-implant supported amda©. In: Park JH, editor. Temporary Anchorage Devices in Clinical Orthodontics. Hoboken, NJ: Wiley-Blackwell 2020; 153-60. [Crossref]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2020.80240

Retraction Notice

The article by Prasad and Kharbanda, entitled "Interdisciplinary Management of an Adult Bilateral Cleft Lip and Palate Patient with Excessive Incisor Display - A Case Report" (Turk J Orthod 2019; 32(3):176-81) has been investigated in terms of text recycling upon receipt of a reader's concern.

The Editorial Board of the Turkish Journal of Orthodontics conducted a thorough investigation following COPE guidelines. The results of the investigation indicated significant overlapping sections with a previously published article from the same authors. Thus, the article in question has been retracted from publication in the Turkish Journal of Orthodontics by the decision of the editorial board of the journal for the reasons listed below.

- Article in question were screened by iThenticate during evaluation process in the Turkish Journal of Orthodontics and the system did not detect similarity with the article published in the Journal of Indian Orthodontic Society. During the text recycling investigation, Turkish Journal of Orthodontics contacted Crossref regarding the issue and was informed that DOI of the first article was not published online until October 2019. Therefore, text recycling could not be detected during evaluation and publication process of the article in question.
- Upon the reader's concern, the article in question was rescreened by iThenticate and it was detected that the aim and conclusion sections of both papers were identical, more than 50% of the discussion sections were also identical.
- Although two different cases were discussed in the papers, the editorial board concluded that the latter publication does not contribute to the literature due to the excessive amount of overlapping sections.

Retracted publication
Interdisciplinary Management of an Adult Bilateral Cleft Lip and Palate Patient with Excessive Incisor Display - A Case Report
Ashish Prasad , Om Prakash Kharbanda
Department of Orthodontics and Dentofacial Deformities, All India Institute of Medical Sciences, Centre for Dental Education and Research, New Delhi, India
opk15@hotmail.com
Turk J Orthod 2019; 32(3): 176-81
DOI: 10.5152/TurkJOrthod.2019.18054

Original publication
Orthodontic management of excessive incisor display of an adult bilateral cleft lip and palate patient
Om Prakash Kharbanda, Ashish Prasad, Rahul Minotra, Shailendra Singh Rana
Division of Orthodontics and Dentofacial Deformities, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi, India
J Indian Orthod Soc 2016;50:116-9
DOI: 10.4103/0301-5742.179945