Official Publication of
Istanbul University
Faculty of Dentistry

European Oral Research

Volume 56 ▪ Issue 2 ▪ May 2022

ISSN print 2630-6158 ▪ ISSN online 2651-2823

EOR

eor.istanbul.edu.tr

Istanbul University Press

European
Oral Research

Official Publication of
Istanbul University
Faculty of Dentistry

INDEXING AND ABSTRACTING

SCOPUS
WEB OF SCIENCE - EMERGING SOURCES CITATION INDEX (ESCI)
PUBMED Central
PROQUEST
EBSCOHOST
DIRECTORY OF OPEN ACCESS JOURNALS (DOAJ)
OPEN AIRE
CHEMICAL ABSTRACTS
GOOGLE SCHOLAR
TUBITAK ULAKBIM TÜRKİYE ATIF DİZİNİ

European
Oral Research

Official Publication of
Istanbul University
Faculty of Dentistry

CORRESPONDENCE ADDRESS

Istanbul University, Faculty Of Dentistry
Prof. Dr. Cavit Orhan Tütengil Sokak No. 4 Vezneciler-Fatih-İstanbul
Phone: +90 (212) 440 00 00 / 12100
E-mail: eor@istanbul.edu.tr
https://dergipark.org.tr/tr/pub/eor
https://iupress.istanbul.edu.tr/tr/journal/eor/home

PUBLISHER

İstanbul University Press
İstanbul University Central Campus,
34452 Beyazit, Fatih / İstanbul, Turkiye,
Phone: +90 (212) 440 00 00

PRINTED BY

İlbey Matbaa Kağıt Reklam Org. Müc. San. Tic. Ltd. Şti.
2. Matbaacılar Sitesi 3NB 3 Topkapı/Zeytinburnu, İstanbul, Turkiye
E-mail: www.ilbeymatbaa.com.tr
Certificate No: 17845

The publication languages of the journal is English.

This is a scholarly, international, peer-reviewed and open-access journal published triannually in January, May and September.

Publication Type: Periodical

European Oral Research

Official Publication of Istanbul University Faculty of Dentistry

EDITORIAL MANAGEMENT BOARD

European Oral Research

Official Publication of Istanbul University Faculty of Dentistry

EDITORIAL ADVISORY BOARD

European Oral Research

Official Publication of Istanbul University Faculty of Dentistry

AUTHOR GUIDELINES

General information

European Oral Research (Eur Oral Res) is an open access, peer-reviewed international title and it is the official scientific publication of Istanbul University Faculty of Dentistry. Eur Oral Res does not charge authors or authors' institutions for submitting, processing or publication of articles. There is no fee for extra pages or color images.

Basic and clinical research papers, case reports and review articles on the main topics of oral and maxillofacial surgery, oral diseases, oral and dental health, oral and maxillofacial radiology, biomaterials, restorative dentistry, periodontics, pedodontics, orthodontics, endodontics, prosthodontics, oral biology, epidemiology, geriatric dentistry and dental education may be submitted for consideration. Letter to the Editor section is also available for authors who wish to comment on previously published articles in the journal. Authors should take collective responsibility for their work and for the content of their publications. Editor-in Chief or the Editorial Board reserves the right to change the format, grammar or sentence structure of any part of the manuscript to comply with the guidelines to fit the standard format and style of Eur Oral Res and scientific journals in general.

Who is an author ?

Eur Oral Res adheres to the International Committee of Medical Journal Editors (ICMJE) standards to define the qualifications of authorship and recommends that it should be based on the following 4 criteria: substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND drafting the work or revising it critically for important intellectual content; AND final approval of the version to be published; AND 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.

Before you begin

Disclaimer and copyright

Submission of a manuscript implies that the work described has not been published before; that it is not under consideration for publication anywhere else entirely or partially, nor will it be submitted for consideration of publication anywhere else until a final publication decision concerning this manuscript has been made by the Editor(s) of the Journal; that its publication has been approved by all co-authors, if any, as well as by the responsible authorities at the institute where the work has been carried out. The publisher cannot be held legally responsible should there be any claims for compensation.

Eur Oral Res provides free access to and allows free download of its contents from the journal's website (http://eor.istanbul.edu.tr/tr/_). Both anonymous or registered users can read and/or download articles for personal use. Unless otherwise indicated, the articles and journal content are licensed under Creative Commons License Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) license (https://creativecommons.org/licenses/by-nc/4.0/). Users must give appropriate credit, provide a link to the license, and indicate if changes were made. Users may do so in any reasonable manner, but not in any way that suggests the journal endorses its use. The material cannot be used for commercial purposes. If the user remixes, transforms, or builds upon the material, he/she may not distribute the modified material. No warranties are given. The license may not give the user all of the permissions necessary for his/her intended use. For example, other rights such as publicity, privacy, or moral rights may limit how the material can be used.

Articles may not be published elsewhere, in whole or in part, electronically or in print, without written permission from the Editor-in-Chief. The responsibility of the content(s) and/or opinion(s) provided in the articles which are published in the print and/or online versions of the journal, belong exclusively to their respective author(s). The publisher/editor/editorial board/reviewers cannot be held responsible for errors, scientific or otherwise, in the contents or any consequences arising from the use of information contained therein. The opinions expressed in the articles published in this journal are purely those of their respective authors and in no way represent the opinions of the publisher/editor/editorial board/reviewers of the journal.

Publication ethics and avoiding allegations of plagiarism

Please refer to http://eor.istanbul.edu.tr/en/content/about/publication-ethics-and-publication-malpractice-statement to consult Eur Oral Res Publication Ethics and Publication Malpractice Statement. By submitting their manuscripts to Eur Oral Res, authors also accept that their manuscripts may be screened for signs of plagiarism using any means necessary and available; including, but not limited to, the use of plagiarism detection software.

Ethical approvals

Experimentation involving human subjects should be conducted in full accordance with the Helsinki Declaration of World Medical Association (http://www.wma.net/en/30publications/10policies/b3/index.html) and legal requirements of the country where the research had been carried out. Manuscript must include a statement indicating that the informed consent was obtained from all participants. A statement confirming that the study has been reviewed and approved by an ethical or advisory board should also be included. The patient's privacy should not be violated. Identifying information such as names, initials, hospital numbers, unnecessary details in photographs should be omitted from the submission. When detailed descriptions, photographs and/or videos of faces or identifiable body parts that might permit a patient to be identified must be included in the submission, authors must obtain written

European Oral Research

Official Publication of Istanbul University Faculty of Dentistry

informed consent for its publication from the patient or his/her parent/guardian.

Experiments on laboratory animals must comply with the Guidelines of the European Communities Council Directive 2010/63/EU and with local laws and regulations. A statement confirming that the study has been reviewed and approved by an ethical or advisory board should also be included (http://www.eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0063).

Clinical trials

Randomized controlled clinical trials should be reported in full accordance with the guidelines available at http://www.consort-statement.org. The CONSORT checklist must be provided in the submission documents. Following free public clinical registries can be used to register clinical trials: http://www.clinicaltrials.gov, http://clinicaltrials.ifpma.org/clinicaltrials/, http://isrctn.org/ . Registration number and project name will be published in the article.

DNA Sequences and Crystallographic Structure Determinations

Manuscripts reporting protein or DNA sequences and crystallographic structure should provide Genbank or Brookhaven Protein Data Bank accession numbers, respectively.

Submission forms

Authors who are willing to submit their manuscripts to Eur Oral Res are required to complete and sign Manuscript Submission Form, Copyright Transfer Agreement form and Disclosure of Potential Conflict of Interest Form. Please send these forms electronically when submitting your manuscript. Article evaluation process cannot be started until all documents are received.

All three documents are available for download at:

http://dishekimligi.istanbul.edu.tr/wp-content/uploads/2015/04/JIUFD-submission-forms.zip

Manuscript preparation

Language

Authors should write their manuscripts in US English. Spelling and phrasing should conform to standard usage and be consistent throughout the paper. Authors whose native language is not English are encouraged either to consult with a native speaker or to collaborate with a colleague whose English skills are more advanced. Authors may also use professional translation services at their own expense. Please note that using language editing services does not imply that the article will be selected for peer-review or be accepted by Eur Oral Res.

Style and format

Use A4 page format in Microsoft Word® software, custom margins (top & bottom 3 cm, left& right 2.5 cm), Times New Roman Font, Font size 12, double line spacing for main text and single line spacing for "References" section. US English grammar check option should be enabled. Words and abbreviations in Latin should be written in italics: "*et al., in vivo, in vitro, in utero, in situ, ad libitum, clostridium perfringens, Staphylococcus aureus*".

Unit abbreviations

Abbreviations used for units, prefixes, and symbols should comply with the International System of Units (SI) (http://physics.nist.gov/Pubs/SP330/sp330.pdf). If this is not possible, SI equivalents must be presented between parentheses. The complete names of individual teeth must be given in the main text (e.g. maxillary right central incisor). FDI 2-digit system should be used in table and figure legends (e.g. 11 for maxillary right central incisor).

Title page

Main title of the manuscript should not exceed 150 characters (including spaces) and it should be written in Times New Roman font, in bold capital letters of 12 font size. A running title not more than 50 characters (including spaces) written in lower case letters must also be provided below the main title. Names, surnames and affiliations of all authors should appear below the running title. Use superscript numbers "1,2,3" for authors from different institutions, do not use any numbers if all authors are from the same department. Name, surname, postal address, phone, fax and e-mail of the corresponding author should be mentioned separately. If the paper has been previously presented in a scientific meeting either orally or as a poster, the title of the manuscript should be followed by an asterisk (*), which refers to a footnote indicating the name of the organization, location and date of its presentation. Please do not use page numbers for this page.

Abstract & Keywords page

This page should start with main and running titles of your manuscript. It should not contain author names, affiliations or any citations. This section must describe the main objective(s) of the study, explain how the study was done without giving too much methodological detail and summarize the most important results and their significance. It should be as clear and concise as possible. Start numbering from this page on and place it at the lower right-hand corner of the page footer. Abstracts should not exceed 250 words for original research papers and should be structured to include Purpose, Materials and Methods, Results, Conclusion headings written in bold letters. Abstracts of case reports and review articles are limited to 150 words and should be unstructured.

If not absolutely necessary, do not include names of statistical tests or software in the Materials and Methods. In Results section, Provide p values between parentheses at the end of the sentence before the period. If p value is lower than 0.05 or 0.01 or higher than 0.05 (not significant), then provide its exact value using a maximum of three digits after the decimal point. If it is lower than 0.001, then use only less-than sign, e.g. p=0.078, p=0.048, p=0.009, p<0.001.

European Oral Research

Official Publication of Istanbul University Faculty of Dentistry

A maximum of five keywords should follow the abstract, preferably chosen from the Medical Subject Headings (MESH) terms (http://www.ncbi.nlm.nih.gov/mesh).

In-text citations

Eur Oral Res recommends the use of reference management software to ensure that the citations are correctly formatted. In-text citations should be numbered consecutively in the order of appearance with Arabic numerals between parentheses and be placed immediately after the author(s)' name(s).

Articles with two authors are cited using their last names separated by "and":

"John and James (1) demonstrated...".

For articles with three or more authors, use the first author's last name followed by "et al.": "James *et al*. (2) showed...".

Multiple quotations used within the same sentence should be cited immediately after each author(s)' name(s).

"John and James (1) and James *et al*. (2) have suggested…"

If author(s)' name(s) are not to be used, the citation number(s) should be placed at the end of the sentence before the period. Use number ranges for consecutive citations.

"The validity and reliability of dental anxiety scales have been evaluated previously (7) or (4, 6, 8) or (12-19)."

Original research articles

Original research articles are limited to 15 pages including main text, references, tables and figures. They should be organized into the following sections:

- Title page
- Abstract & Keywords
- Introduction
- Materials and Methods (or Subjects and Methods)
- Results
- Discussion
- Conclusion
- Acknowledgements (optional)
- Source of funding
- Conflict of Interest
- References

Introduction should provide a concise account of the research problem and introduce the reader to the pertinent literature. The objective(s) and/or hypothesis of the study should be clearly stated in the last paragraph. Writing style of this section should allow the readers outside the field of your expertise to understand the purpose and significance of the study.

Materials and Methods section should describe the study population/sample or specimens, the variables and the procedures of the study with sufficient detail to ensure reproducibility. Standard methods already published in the literature could be briefly described and the original reference should be cited. If your research includes direct involvement with human subjects, use 'Subjects and Methods' heading instead of 'Materials and Methods'.

Feel free to use sub-headings written in italic letters (but not bold) to improve readability of your manuscript such as Population characteristics, Immunohistochemical staining, Experimental protocols or Light microscopy evaluation.

Include ethical approvals for clinical trials and animal studies in the first paragraph of this section. Provide the name of the responsible organization, year of approval and project number:

This project has been reviewed and approved by the Ethical Committee of Istanbul University, Faculty of Medicine (2012/891-1085).

Include Brand name, Manufacturer, City, (state abbreviation for USA), Country details for each material used in the experimental protocol:

DNA was extracted using a MagNA Pure-Compact DNA Isolation Kit (Roche Diagnostics GmbH, Mannheim, Germany)

Bone grafts were fixed with 2 mm bioresorbable screws (Inion CPS system, Inion OY, Tampere, Finland).

Statistical analysis sub-heading must be included as the last paragraph of this section. Authors should provide the name of the statistical software, report which types of descriptive statistics were used to summarize the data, indicate how the distribution of the data was tested for normality assumptions (if applicable), which tests were employed to answer each hypotheses, the confidence interval and p values to determine the level of significance. Consult SAMPL guidelines for more detailed information on statistical reporting in biomedical journals: http://www.equator-network.org/wp-content/uploads/2013/07/SAMPL-Guidelines-6-27-13.pdf

Provide Name, Version, Company, City, (state abbreviation for USA), Country for statistical software:

GraphPad Prism version 3.0 statistical analysis software (GraphPad Software Inc., San Diego, CA, USA)

The following paragraph is a sample for statistical analysis section; please alter the paragraph so that it fits your study:

The collected data from all groups were imported to Statistical Package for Social Sciences (SPSS) for Windows software, version 16.0 (SPSS Inc., Chicago, IL, USA). The standard descriptive methods such as the mean, standard deviation, median, frequency, minimum and maximum were applied to determine the characteristics of the sample. The chi-square test was used to compare the categorical demographic variables among the groups. Because the distribution of the data did not meet the requirements for normality and homogeneity of variances assumptions, the nonparametric Kruskal-Wallis one way analysis of variance by ranks and Mann-Whitney U tests were used for the multiple and pairwise comparisons, respectively. The correlations between at least two continuous variables were examined using Pearson's correlation coefficient. Stepwise regression analysis was performed to understand the statistical dependence of the DFS and MDAS scores in the general population. Covariance analysis was used to determine whether the difference between the mean DFS and MDAS

scores of the groups was statistically significant under a predefined effect. The confidence interval was set to 95% and $p < 0.05$ was considered statistically significant.

Results should be written clearly without subjective interpretation and be supported with tables and figures when necessary. Text should complement any figures or tables but it should not repeat the same information. When reporting your findings, follow the same order you have used in "Materials and Methods" section.

Use a maximum of two digits after the decimal point for descriptive statistics such as mean and standard deviation: "45.66±23.48". If the last digit is 0 then use : "45.6±23.4".

Provide p values between parentheses at the end of the sentence before the period. if p value is lower than 0.05 or 0.01 or higher than 0.05 (not significant) then provide its exact value using a maximum of three digits after the decimal point. If it is lower than 0.001, then use only less-than sign, e.g. (p=0.078), (p=0.048), (p=0.009), (p<0.001).

In the **Discussion** section, authors should state major findings, their meanings and clinical relevance, present any contrasts with the results of similar studies, describe unavoidable limitations in the study design and make suggestions for further research within the limits of their data. When discussing your findings, use the same logical order as in the Results section.

Conclusion should be supported by results and must be consistent with the objectives of the research.

Case reports/Case series

Case reports/Case series should not exceed 7 pages and a maximum of 6 tables or figures. They should make a significant contribution by presenting unusual occurrences of rare entities and/or highlight the need for revision of current therapeutic options. This type of manuscript should be organized as follows:

- Title page
- Abstract & Keywords
- Introduction
- Case report (or case series)
- Discussion
- Conclusion
- Acknowledgements (optional)
- Source of funding
- Conflict of Interest
- References

Narrative or systematic reviews and meta-analyses

Narrative review articles are limited to 10 pages including the main text, references, tables and figures. The manuscripts should summarize the current state of understanding on a particularly important topic in dentistry based on previously published data, preferably written by authoritative figures of that field. A minimum of 50 references must be cited. Authors are encouraged to use headings of their own choosing between Introduction and Conclusion sections.

This type of manuscript should be organized as follows:

- Title page
- Abstract & Keywords
- Introduction
- Conclusion
- Acknowledgements (optional)
- Source of funding
- Conflict of Interest
- References

Authors who are willing to submit a systematic review or a meta-analysis may use the same manuscript design as for the original research articles.

Letter to the Editor

Letters to the Editor are short articles (limited to 500 words and 5 references) in which readers can share their opinions and comment on articles published in the past 12 months. Authors should clearly cite the article to which they are referring. Letters will be evaluated by the Editor-in-Chief and, if accepted for publication, the author(s) of the original paper will be invited to submit a reply.

Acknowledgements

This section is optional. Authors must acknowledge all individuals who do not fulfill the requirements for authorship but who had contributed to the preparation of the manuscript by providing assistance in writing, literature search, data analysis and/or supply of materials.

Source of funding

This section is mandatory to be filled out. Financial support from any institutional, private or corporate sources must be disclosed. Clearly state the name of the funding organization, year and the project number:

"This study has been supported by a research grant from XXX foundation, university, government etc.. (project number: 2012/828128)

If you have no source of funding declaration to make, please write "None declared".

Conflict of Interest

This section is mandatory to be filled out. Any financial or personal activities (royalties, grants, consultancy fee, patent registration, ownership, employment) that could be perceived as potential conflicts of interests must also be disclosed.

Clearly state the names of the author(s) and organization(s) and the type of payment(s):

"Dr. Smith is a consultant for the company X / receives a consultancy fee from the company X." or "Until recently, Dr. Smith was in an employment relationship with the company Z." .

If you have no declaration to make, please write "None declared".

References

Eur Oral Res recommends the use of reference management software to ensure that the references are correctly formatted. All authors must be included in this section, in contrast to the in-text citations. Journal abbreviations should be formatted according to the PubMed - NLM Journal Title Abbreviations (http://www.ncbi.nlm.nih.gov/journals). Au-

European Oral Research

Official Publication of Istanbul University Faculty of Dentistry

thors are advised to consult a recent issue of the journal. Use single line spacing for this section. Please do not cite unpublished articles, abstracts, personal communications, non-scientific websites or documents such as pamphlets.

AUTHORS ARE RESPONSIBLE FOR SENDING THE FULL TEXT VERSIONS OF ANY CITED PAPER OR TEXTBOOK AS PER THE REQUEST OF THE EUR ORAL RES EDITORIAL BOARD AND/OR THE REVIEWERS.

AUTHORS ARE RESPONSIBLE FOR SENDING THE PROFESSIONAL ENGLISH TRANSLATION OF ANY NON-ENGLISH PAPER OR TEXTBOOK AS PER THE REQUEST OF THE EUR ORAL RES EDITORIAL BOARD AND/OR THE REVIEWERS.

Journal Article in Print

1. Burrow MF, Tagami J, Negishi T. Early tensile bone strengths of several enamel and dentin bonding systems. J Dent Res 1994; 74: 522-8.

Journal Article Electronic Publication Ahead of Print

2. McKeage K. Tobramycin inhalation powder: a review of its use in the treatment of chronic pseudomonas aeruginosa infection in patients with cystic fibrosis. Drugs 2013; [Epub ahead of print] Available from: http://link.springer.com/article/10.1007%2 Fs40265-013-0141-0

Book

3. Mueller HJ, Freeman D. FT-IR spectrometry in materiolography. 2nd Ed., Ohio: American Society for Metal 1994, p.51-56.

Chapter in a book

4. Alexander RG. Considerations in creating a beautiful smile. In: Romano R, editor. The art of the smile. London: Quintessence Publishing, 2005, p.187-210.
5. Hudson FB, Hawcroft J. Duration of treatment in phenylketonuria. In: Seakins J, Saunders R, editors. Treatment of inborn errors of metabolism. London: Churchill Livingstone, 1973, p.51-56.

Thesis

6. Maden I. Effect Of Nd:YAG Laser Treatment In Addition To Scaling And Root Planning. Doctoral Dissertation, Istanbul University Institute of Health Sciences Periodontology Department, 2009.

Tables, Figures and Legends

Please set table format to custom borders, no vertical lines, no shades, no background colors, 3 pt line for top and bottom borders, 1 pt horizontal row lines, cell alignment center. Tables should be numbered consecutively with Arabic numerals in the order mentioned in the text. All tables must be included in the main body of the article and be placed near their first mention in the text. All tables should be self-explanatory. Please provide full explanation for abbreviations even if they were presented in the main text. Legends should be written in Times New Roman Italic font and be positioned right above the table.

Figures (photographs, graphs, charts, drawings, pictures, etc.) should be numbered consecutively with Arabic numerals in the order of mention in the text. High quality pictures with 300 dpi resolution in JPEG JPG, BMP, TIFF, PNG or PSD file formats are generally acceptable for publication. Drawings and shapes should be in vector format. All figures must be included in the main body of the article and be placed near their first mention in the text. Legends should be written in Times New Roman Italic font and be positioned below the figure.

Figure 1. Panoramic radiograph of the patient taken 6 months after surgery, note irregular borders of the lesion.

Submission checklist

1. "Manuscript Submission Form" signed by the corresponding author.
2. "Copyright Transfer Agreement Form" signed by all authors.
3. "Disclosure of Potential Conflict of Interest Form" signed by all authors.
4. Title page
5. Abstract & Keywords page
6. Main text
7. Tables, figures and their legends should be embedded in the main text and are not to be sent separately.

How to submit ?

Eur Oral Res is only accepting electronic submissions. Manuscripts may be submitted by registering at https://mc04.manuscriptcentral.com/eores

Need assistance ?

Please contact editorial office by sending an e-mail to: dentistryeditor@istanbul.edu.tr or disdergi@istanbul.edu.tr

Postal address: İstanbul Üniversitesi Diş Hekimliği Fakültesi Dergisi İstanbul Üniversitesi Diş Hekimliği Fakültesi Kütüphanesi Dergi Yayın Kurulu Odası 34093 Çapa-Fatih, İSTANBUL/TURKEY

Phone: +90 212 414 20 20 (extension 30348)
Fax: +90 212 414 25 70

What's next ?

If you have successfully submitted your forms and manuscript, please continue reading this document to know about the Eur Oral Res editorial process.

General information

Peer-review evaluation and publishing of articles submitted to Eur Oral Res are managed electronically through the online system via e-mail correspondence. Corresponding authors will be notified by e-mail upon receipt of a new manuscript and will have further information regarding the editorial process. It is the responsibility of the corresponding author to communicate with the other participants of the study about the submission of the manuscript, its content and authorship requirements.

Who makes the decisions ?

Eur Oral Res Editorial Board oversees the manuscript evaluation process. The Editor-in-Chief is the only person who can officially accept a paper.

European Oral Research

Official Publication of Istanbul University Faculty of Dentistry

Initial examination

Editor-in-Chief and editorial assistants check the submission files to confirm the availability of the required documents. Please note that the Manuscript Submission Form, Copyright Transfer Agreement Form and Conflict of Interest Disclosure Form must be included in the original submission. Corresponding authors of incomplete submissions will be notified via e-mail. Editorial process cannot proceed until all relevant documents are signed and submitted electronically.

Careful manuscript preparation is the crucial part of peer-review process. Editorial assistants will evaluate the manuscript to ascertain conformity to the following standards: consistency to journal style, clear and concise writing, proper use of English grammar and spelling, technical quality, correct formatting of references and documentation of ethical conduct. All eligible manuscripts will also be scanned with anti-plagiarism software.

Manuscripts that fail to conform to journal expectations in any of the above mentioned issues will be returned to authors without review. This is a frequent cause of delay in the publication of articles and may even result in immediate rejection. All issues regarding the outline of the manuscript should be resolved before further evaluation. Manuscripts which pass the initial examination are presented to the Editorial Board by the Editor-in-Chief.

Peer-review

Eur Oral Res operates a double-blind peer review system. Identities of the Editorial Board members who perform the initial examination and those of the reviewers who evaluate the manuscript remain unknown to the authors. All manuscripts are treated as privileged information. Editorial Board members and reviewers are instructed to exclude themselves from reviewing any manuscripts that might involve a conflict of interest.

Editorial Board requests the opinion of, at least, two independent expert reviewers. Those who accept the invitation are expected to provide written critical reviews of the submission within 21 days of receipt. If one of the reviewers gives a negative feedback while the other's response is positive, Editor-in Chief or Editorial Board invites a third reviewer. Editor-in-Chief and Editorial Board reserve the right to obtain reports from biostatistics experts of their choosing at any time during the process, who might also suggest corrections in the manuscript.

21 day time limit will apply for the correction of the manuscript, at the end of which the corresponding author must return a revised version of the documents. Changes should be highlighted in red in the revised manuscript to facilitate reading. Authors should also provide itemized, point-by-point responses to reviewers' comments in a separate file. The manuscript will be automatically rejected if no answer has been received from the authors. If authors submit the revised paper after the time limit is reached, it will be treated as a new submission. Revised manuscripts will be re-evaluated by Editor-in-Chief and Editorial Board and will be sent back to reviewers.

Acceptance for publication requires at least, but not limited to, final positive responses from two reviewers. In light of their recommendations, the Editor-in-Chief and the Editorial Board members choose between the following options: "accept submission", "revisions required", "resubmit for review" or "decline submission".

"Accept submission" indicates that the manuscript can be published as is. If there are "revisions required", all major changes in the manuscript must be confirmed by the reviewer who had originally suggested the revisions. In some cases, editorial team may think that your manuscript deserves re-evaluation after substantial changes which cannot be completed within reasonable time limits. Therefore, the editor may encourage authors to re-submit their manuscript by selecting "resubmit for review". Such conditions include, but not limited to, increasing the sample size, performing more statistical tests or correcting multiple errors that impede understanding. Re-submitted manuscripts will be treated as new submissions. On the other hand, if the "decline submission" decision has been reached, your manuscript has been found unsuitable for publication and you cannot submit the same manuscript to this journal.

An e-mail notification that includes the formal letter of approval will be sent to the corresponding author. Rejection e-mail will include reviewers' comments and suggestions. Accepted manuscripts will be forwarded to the publisher.

Table 1. *Concise explanation of the table contents (SD: standard deviation, CTA: cartilage tissue area, NBA: new bone area).*

	Control group (Mean % ± SD %)	First group (Mean % ± SD %)	Second group (Mean % ± SD %)
CTA	21.41 ± 4.2	2.5 ± 2.4	11.42 ± 4.2
NBA	11.48 ± 0.2	21.41 ± 14.22	11.41 ± 4.2

After acceptance

Production department transforms the manuscript files into an article and sends the galley proofs to the corresponding author via e-mail. All authors should carefully check the final PDF proof version of the article for minor punctuation or spelling errors, correct presentation and positioning of the tables, figures and their captions. Corrected page proofs should be returned via e-mail within 7 days of receipt. Major changes such as adding new paragraphs, changing the title or the name order of the authors and modifying visual elements will not be allowed at this stage.

Publication

Articles will normally appear in the order in which they were accepted as publication,

however, Editor-in-Chief and Editorial Board reserve the right to modify this schedule in the presence of critical scientific issues.

To speed up the process, articles will be first published online, followed by the print version of the journal. Both versions will have identical page numbers. Therefore, no change can be made in the article in between the online and in print publication steps.

DOI number

Digital Object Identifier (DOI) number is a unique alphanumeric identifier assigned by a registration agency. Once it is assigned to an article, the DOI will never change, therefore, it is ideal for citing and linking electronic documents. Your article will be assigned a DOI number provided by the CrossRef registration agency, immediately after it is published online.

Changes to authorship

This statement concerns the addition, deletion, or rearrangement of author names in the authorship of accepted manuscripts. Requests to add or remove an author or to rearrange the author names must be sent to the Editor-in-Chief from the corresponding author of the accepted manuscript. This document must include: the reason the name should be added or removed, or the author names rearranged and written confirmation (e-mail, fax, letter) from all authors that they agree on the addition, removal or rearrangement. In the case of addition or removal of authors, written confirmation from the author being added or removed must be included. Requests that are not sent by the corresponding author will be forwarded by the Editor-in-Chief to the corresponding author, who must follow the procedure as described above. Production of the accepted manuscript is suspended until authorship has been agreed. The name and the order of the authors cannot be changed once the article is published online or in print.

Data access and retention

Authors may be asked to provide the raw data of their investigations during the editorial process or after publication of the article. Such materials include, but not limited to, original submission files, unedited versions of the printed and/or digital radiographs, unedited versions of the printed and/or digital photographs, histologic slides, original outputs from clinical and/or experimental diagnostic and/or interventional devices, original data sheets of statistical software and technical data sheets of any substance used in the research project. Authors should retain such materials for a reasonable period of time after the publication of their paper.

Correction, Retraction & Removal

A formal correction will be issued in the journal by the Editor-in-Chief, if only a small portion of otherwise reliable article is flawed in a way that does not severely affect the findings reported in it (such as mistakes in the spelling of a drug, miscalculation of a formula, mismatch between images and their captions or incorrect author list). Online articles will not be corrected directly. An erratum (for publishing error) or a corrigendum (for author error) will be published in the next issue of the journal.

Articles may be retracted by its authors or by the Editor-in-Chief under the advice of the scientific community. If authors are willing to retract an article before it is published (accepted or under review), requests must be sent to the Editor-in-Chief from the corresponding author of the manuscript. This document must include: the reason the article should be retracted and written confirmation (e-mail, fax, letter) from all authors that they agree on the retraction. Reasons for editorial retraction include, but not limited to, unreliable publications as a result of misconduct or honest error, redundant publication, major plagiarism, copyright infringement and unethical research. A formal retraction announcement written by the Editor-in-Chief will be published in the print edition of the journal. For online articles, the PDF pages remain with a watermark on each page to notify it is retracted.

In rare circumstances, an article can be completely removed from the online database. Such conditions include, but not limited to, defamation, infringement of legal rights, court orders and claims in the article that might pose serious health risks. Title and author names will remain in the web page while the text will be replaced by a notification indicating that the article has been removed for legal reasons.

European Oral Research

Official Publication of
Istanbul University
Faculty of Dentistry

Contents

Original Research Articles

eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2022; 56(2): 55-60

Original research

Shear bond strengths of five porcelain repair systems to zirconia infrastructures

Sirageddin Al-hmadi[1],
Funda Erol[2],
Melahat Güven Çelik[2]

Purpose
This study aimed to investigate the effect of five porcelain repair systems on shear bond strength in composite and zirconia infrastructures and to identify the bond failure mode after thermocycling.

Materials and Methods
Disk-shaped zirconia samples (n=50) were divided into five groups (n=10) according to repairing system type. Each repair system was applied to the zirconium samples and a hybrid composite was used for repairing. Shear bond testing of all groups was carried out using a universal testing machine after thermocycling.

Results
Repair systems demonstrated no significant difference in repairing zirconia except Single Bond. Single Bond was the weakest in repairing the infrastructures. The highest and lowest mean bond strength values for the zirconia groups were 18,91 MPa and 3,63 MPa, respectively.

Conclusion
The three repair systems, Ivoclar, Clearfil, and Bisco, were more effective than the Single Bond and Ultradent repair systems in repairing zirconia, and their bond failure modes were both mixed and adhesive.

Keywords: *Repair system, zirconia, shear bond, adhesive system, bond failure*

Introduction

Although the use of all-ceramic restorations have become widespread in recent years due to their aesthetic superiority, metal-ceramic restorations are still the most frequently used restorations due to their mechanical durability (1,2). Due to the increasing cost of gold alloys in the 1960s, the use of alternative alloys for prosthetic restorations became more popular. The mechanical properties of these materials allow for thinner but more robust restorations (3). Due to cost and rigidity nickel-chromium and cobalt-chromium alloys are preferred (4).

The increase in the aesthetic expectations of individuals in recent years has led to the development of different types of dental ceramic restorations (5–7). The chemical properties of the ceramics and their superior performance in mimicking dental tissues were the main reasons behind the widespread use of these dental materials (8). Zirconium material was first introduced in dentistry in 1990 as a crown prosthesis and as an infrastructure material in fixed prostheses (9).

Most all-ceramic materials have been developed to achieve esthetic restoration. One of the most used all-ceramic esthetic restorations is zirconia, which differs from others by its resistant mechanical properties. Zirconia has three forms: monoclinic, tetragonal, and cubic; it structure is

ORCID IDs of the authors: S.A. 0000-0002-2335-9441; F.E. 0000-0002-8272-3733; M.Ç.G. 0000-0002-0896-2920

[1]*Private practice, Istanbul, Turkiye*

[2]*Assistant Professor, Department of Prosthodontics, Istanbul Yeni Yüzyıl University, Istanbul, Turkiye*

Corresponding Author: Funda Erol

E-mail: fundacalisir@gmail.com

Received: 3 August 2020
Revised: 21 November 2020
Accepted: 17 January 2021

DOI: 10.26650/eor.2022962372

How to cite: *Al-hmadi S, Erol F, Celik Guven M. Comparison of shear bond strength of five porcelain repair systems to zirconia infrastructures. Eur Oral Res 2022; 56(2): 55-60. DOI: 10.26650/eor.2022962372*

monoclinic at room temperature and transforms to the cubic and tetragonal phases with increasing temperature (9).

Porcelain veneer fractures have been reported to be the most common reason for the replacement of metal-ceramic crowns and bridges (10,11). The failure of veneered porcelain may occur from inadequate metal framework design, tooth preparation and occlusal adjustment (12,13).

The most frequent complication is the small chip-off fracture of veneered ceramic. Although replacing them with ceramic restorations is a common approach, they can be repaired intraorally when they are not completely damaged (14–16). During the replacement of a fractured ceramic restoration trauma may damage the remaining teeth and tissues. This procedure costs more than repairing the chipped part (17). Numerous commercial intraoral ceramics repairing systems has been developed for repairing these kinds of restorations. On the other hand, scientific studies reveal that ceramic repair systems cannot create a persistent solution due to their weakened bond strength (18,19).

The bonding strength between the cracked restoration and the repair material must be strong enough. When the bond strength of ceramic repair systems is at clinically acceptable levels, the time and money spent on making a new restoration will be reduced (7).

In the present study, five ceramic repair systems were used to simulate chairside zirconia infrastructure repair using composite resin. The aim was to compare the effects of the five repair systems on the shear bond strength (SBS) between the composite and zirconium to analyze the mode of failure in each experimental group. The null hypothesis is as follows: there is no difference in the bond strength of the different ceramic repair systems in repairing a zirconia infrastructure.

Materials and methods

Study design and sample preparation

50 disk-shaped zirconia samples with a 10 mm diameter and a 3 mm thickness were used in the present study. The zirconia disks were prepared from presintered blocks (H.C. Starck, Berlin, Germany) according to the manufacturer's instructions using a CAD/CAM system (CORITEC T 350i loader, imes-icore, Eiterfeld, Germany) and sintered to the final required dimension (10 mm in diameter and 3 mm thick) in a special high-temperature furnace. Table 1 shows the materials used and their manufacturer's information.

All disk specimens were properly polished by a special polishing machine (Tegrapol-11;Struers, Ballerup, Germany) using wet silicon carbide paper ground with 600, 800, and 1,000 grit under cool water for 1 min. All zirconia disks were treated with airborne-particle abrasion device (Airsonic Mini Sandblaster, Hager & Warken, Duisburg, Germany) with a 50-µm particle size aluminum-oxide for 10 seconds at a pressure of 0,3 MPa and from 10 mm distance.

The repairing procedure was performed by the same operator (S.A.). Each repair system used in this study was applied to the zirconium samples according to the manufacturer's instructions, as explained in Table 2.

Hybrid composite resin was incrementally packed with a hand instrument using a specially designed epoxy glass mold (6 mm diameter and 3 mm thickness). Each layer was light-cured with a light polymerizing unit (3M Elipar S10, 3M Espe, Germany) for 40 s at a distance of 1 mm with an output of 1,000 mW/cm2. The wavelength of the light polymerizing unit was measured by a spectroradiometer (Model 77702, Oriel İnstrument, Danbury, CT, USA), power density was measured using a radiometer (Radiometer LED, Demeton/Kerr, Danbury, CT, USA) prior to every specimen curing.

The bonding process was conducted by the same operator during experiments. After polymerization, the assembly of the repaired samples was removed from the mold, and light curing was repeated in five aspects of all blocks (upper and lateral) for 20 s per side.

Experimental groups

The samples (N = 50) were divided into five groups (n = 10): zirconia with the Bisco repair system (ZB), zirconia with the Clearfil repair system (ZC), zirconia with the Ivoclar ceramic repair system (ZI), zirconia with Single Bond (ZS), and zirconia with the Ultradent repair system (ZU).

Thermocycling protocols

The samples were all stored in distilled water at 37 °C for 24 hours and then subjected to thermal cycling (Slibrus Technica Termal Siklus, İstanbul, Turkey) of 1,200 cycles at 5–55 °C, with a dwell time of 20 s at each temperature and a transfer time from one bath to the other of 10 s.

Testing protocols

All samples were fixed by chemically cured acrylic resin in a steel mold. Shear bond testing of all groups was carried out using universal testing machine (Instron 3345, Instron Corp., Norwood, Illinois, USA) at a crosshead speed of 1 mm/min. SBS values were calculated by dividing the maximum load at failure (N) by the bonding area (mm^2) and recorded in megapascals (MPa). The failure modes of the bond related to the fractured surfaces were analyzed visually by using a stereomicroscope (EMS-405, Esman, Turkey) at 20x magnification. The failure areas were classified as adhesive, cohesive, or mixed type.

Statistical analysis

Statistical analyses were performed by the Number Cruncher Statistical System 2007 (NCSS, Utah, USA) software for Windows. The Shapiro–Wilk test was used to analyze if the measured parameters met the assumptions of normal distribution. The results of the test indicated that the data were normally distributed. Therefore, data were analyzed using the one-way ANOVA and the Tukey's HSD was performed to determine the group responsible for the difference. p-values less than 0.05 were considered statistically significant.

Results

Table 3 shows maximum, minimum, mean values and standard deviation values of the SBS test for the groups. The lowest and highest mean bond strength values for the zirconia groups were 18,91 MPa and 3,63 MPa respectively. When the SBS values of the repair systems applied to the zirconia groups were compared, both Ultradent (ZU) and single bond (ZS) repair systems showed lower SBS values than the

Table 1: *Details of the materials used in the study.*

Material	Composition	Manufacturer	Lot no.
Zirconia (Z)	$ZrO_2/HfO_2/ Y_2O_3$>99, Al_2O_3 <0.10, Fe_2O_3 <0.10, $Na_2 O_3$<0.04)	H.C.Starck, Berlin, Germany	50574292 50575967
Clearfil repair system (C)	K-etchant gel: 40% phosphoric acid Clearfil-SE Bond Primer: 10-methacryloyloxydecyl dihydrogen phosphate (MDP), HEMA, dimethacrylate monomer, water, photoinitiator, Clearfil-SE Bond: silanated colloidal silica, Bis-GMA, 10-MDP, Clearfil Porcelain bond activator: bisphenol A polyethoxy dimethacrylate 3-methacryloyloxypropyltrimethoxy silane (MPS)	Kuraray Co., Osaka, Japan	000016
Bisco repair system (B)	9.5% Hydrofluoric acid Silane with methacrylate Solution: Alcohol One step: bis-GMA, BPDM, HEMA, CQ, p-dimethylaminobenxoic acid (co-initiator), acetone, 8.5% glass fillers	BISCO Dental Products, Illinois, U.S.A.	1700001601
Ivoclar repair system (I)	Monobond® Plus a Primer: Alcohol solution of silane methacrylate, phosphoric acid methacrylate and sulphide methacrylate. Heliobond – a light-curing bonding agent: Bis-GMA and tri-ethylene glycol dimethacrylate (99 wt.%), initiators and stabilizers (<1%).	Ivoclar Vivadent Inc., Liechtenstein, Switzerland	T42712
Ultradent repair system (U)	Etch: 9% hydrofluoric acid, Ultradent silane: 8% methacryloxypropyl-trimethoxysilane, isopropyl alcohol, acetic acid, Peak Universal Bond: 7.5% ethyl alcohol, 0.2% chlorhexidine, methacrylic acid, 2-HEMA	Ultradent Products GmbH, Cologne, Germany	BBFC4
Single bond (S)	MDP Phosphate Monomer, Dimethacrylate resins, HEMA, Vitrebond Copolymer Filler, Ethanol, Water, Initiators, Silane	3M, ESPE, St., Paul, MN, USA	604724
Filtek Z250 (shade C2)	Matrix: Bis-GMA, Bis-EMA, UDMA, TEGDMA, Filler: zirconia, Silica	3M, ESPE, St., Paul, MN, USA	N566178. N545065

Table 2: *Application procedures and contents of the repair systems used in this study.*

	Application procedures	Content
Bisco Repair System (B)	1.Apply 1 coat of Z-PRIME Plus to the exposed zirconia, dry with an air syringe for 3-5 seconds. 2.Apply a thin layer of PORCELAIN BONDING RESIN to the repair site. Spread composite evenly over the surface and light cure. 3. Repair was completed using composite resin and light cured fo 40 seconds	Porcelian etchant Porcelian primer Opaquer catalyst Opaquer Base Universal Z-Prime Plus Porcelain bonding resin
Clearfil Repair System (C)	Clearfil SE Bond Primer and porcelain bond activator were mixed for 5 seconds 2.Bonding agent was applied for 10 seconds (air drying) and photo-polymerization for 40 seconds) 3. Repair was completed using composite resin and light cured fo 40 seconds	K-etching gel Clearfil SE Bond Porcelian bond activator
Ivoclar Repair System (I)	1.Monobond Plus was applied and allowed to react for 60 seconds and after air dried. 2.Thin layer of Heliobond was applied and light cured for 90 seconds 3. Repair was completed using composite resin and light cured fo 40 seconds	IPS Empress Direct Opaque Monobond Plus Heliobond
Ultradent Porcelian Repair system (U)	1.Apply Hydrofloric acid on metal surface for 90 second 2.Apply silane and leave 1 minute 2.Apply Peak Universal bond for 10 second and light cure for 20 second	PermaFlo Dentin Opaquer EtchArrest OpalDam Peak Universal Bond Porcelain Etch Ultradent Silane
Single Bond universal adhesive (S)	1.Apply on surface of Zirconium leave it for 20 second dry with air for 5 second 2.Light cure for 20 seconds	Single bond universal adhesive

Table 3: *Shear bond strengths values (MPa) of the groups.*

Groups (n=10)	Minimum	Maximum	Mean	Std. Deviation
ZB	14,29	27,65	18,91	4,33
ZC	9,33	28,37	18,61	5,37
ZI	8,76	23,51	15,24	5,30
ZS	2,73	4,80	3,63	0,62
ZU	4,99	9,87	6,63	1,50

Table 4: *Pairwise comparisons of the repair systems.*

Tukey Multiple Comparisons Test	P
ZS/ZB	**0,0001**
ZS / ZC	**0,0001**
ZS / ZI	**0,0001**
ZS / ZU	0,447
ZB / ZC	0,999
ZB / ZI	0,249
ZB / ZU	**0,0001**
ZC / ZI	0,331
ZC / ZU	**0,0001**
ZI / ZU	**0,0001**

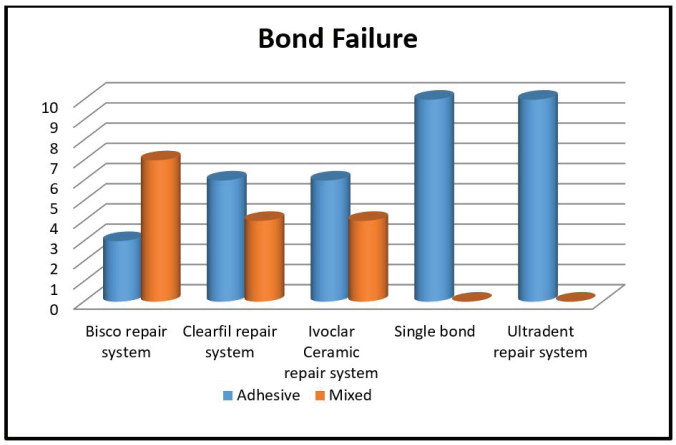


Figure 1. *Failure modes of the groups.*

remaining repair systems (p<0.0001). Bisco (ZB), İvoclar (ZI) and Clearfil (ZC) repair systems showed similar SBS values. Table 4 shows multiple comparisons of repair systems. For the failure modes of the repair systems, Ivoclar (ZI), Clearfil (ZC), and Bisco repair systems (ZB) had both mixed and adhesive failures. All the specimens of the Single Bond (ZS) and Ultradent (ZU) groups failed adhesively (Figure 1).

Discussion

Veneering porcelain fracture is a common complication that can occur in all dental ceramic systems. The incidence of chipping fractures is significantly higher for metal-ceramic and zirconia-based fixed dentures than for framework fractures. For both restorations, veneer chipping can be treated by polishing or repairing rather than replacing the restorations (20).

Five different repair systems were compared in this study. According to the results of the study, the null hypothesis was rejected. The SBS of zirconia to composite resin was significantly different among different repair systems. The samples were subjected to thermocycling for 1,200 cycles at 5–55°C. According to Gale and Darvell (21-23), 10,000 cycles could represent a year of service, as 20–50 cycles are equal to one day. The thermal cycle procedure has been applied similarly in many other studies, and thus we used the same protocol to compare our results with theirs.

Generally, shear bond tests or tensile bond tests are used to measure bond strength. The tensile bond strength test is extremely affected by sample form and the formation of non-uniform stress distributions throughout load applications. The shear bond strength test is the most widely used test for bond strength because of its simple usage, clear test protocol, and rapid production of the test result (23,24). For these reasons, the shear bond tests were performed to evaluate the bond strength in our study as in previous studies (23-25).

Sandblasting provides micromechanical retention and a stronger composite-metal bond when performed on zirconia. In comparing the different repair systems in this study, the surface treatments were not changed, and the sandblasting process, which is one of the most effective methods, was performed for all groups (25). Matsumura *et al.*(26) reported the SBS value of 10 MPa as the minimal to obtain clinically acceptable results. According to the results of the present study, all the repair systems, except ZS and ZU, have exceeded 10 MPa. Statically significant differences were found between the repair systems, and thus the null hypothesis was rejected. Kocaagaoglu and Gurbulak (27) evaluated the SBS between two porcelain repair kits and zirconia or a nonprecious metal alloy. After thermocycling for 1,200 cycles, the SBS of the zirconia group using the Clearfil repair system was 8.80 MPa, and the SBS of metal was 19,75 MPa. We evaluated the SBS of the five porcelain repair systems and the zirconia infrastructure materials after thermocycling for 1,200 cycles. The result of the Clearfil repair system was 18,61 MPa. The difference may be due to the use of a rotary cutting instrument, as 30 µm is not sufficient to roughen a zirconia surface. Zirconia has superior hardness and needs to be ground with coarse diamond rotary instruments (28). Goncalo et al. tested the effect of a surface treatment and primer application on the composite SBS to zirconia. The zirconia prime plus group, which is present in the Bisco repair system and is similar to our ZB group, was higher, and the scores were similar to those in our study (29,30).

Han *et al.* (30) investigated the effects of three intraoral ceramic repair kits on the bond strength between composite resin and zirconia. The SBS was found to be 3.21 MPa for

a ceramic repair system (Ivoclar), 7,80 MPa for a CoJet repair system, and 8,98 MPa for a Signum Zirconia Bond (30). The SBS of the ceramic Ivoclar repair system was weak even without thermocycling. The score for Ivoclar of the ZI group in our study was 15,24 MPa, which was higher than that in the previous study. This may be due to the fact that a zirconia surface should be sandblasted, which is a more effective method for roughening a zirconia surface. Kocaoğlu *et al.* (31) examined the effect of three intraoral ceramic repair systems on the bond strength between composite resin and zirconia (31). The SBS was 10,85 MPa for the Clearfil repair system and 12,64 MPa for the Bisco intraoral repair kit. Compared with the results of our study, the results were lower in Kocaoğlu *et al.'s* study (31). We sandblasted the zirconia samples before application, and this could have enhanced the retention.

No significant difference was found among Clearfil, Bisco, and the ceramic repair system used for repairing the zirconia infrastructure properly because the three repair systems, which contained bonding agents and organo-phosphate monomers (e.g., 10-methacryloxydecyl dihydrogen phosphate [MDP]), were developed to improve the bond strength of resin-based materials to a silica-free zirconium structure (32, 33). Previous studies showed that commercial phosphate-monomer-containing zirconia primers, improved both the initial and long-term resin bond strength to zirconia ceramic sutructures significantly (34–40). The pretreatment of zirconia with MDP-containing adhesive systems can lead to satisfactory adhesion between the different composite resins and ceramic surfaces even after the artificial aging process (41). Moreover, similar to our study, the surface treatment of air-abrasion and phosphate-monomer-containing primer application improved the durability of zirconia-resin bond strength (42–45).

A significant difference was found among the three repair systems (Bisco, Ultradent, and Clearfil) and between the other two repair systems (Ultradent and Single Bond adhesive), probably because Ultradent and Single Bond adhesive depend on silane as a surface treatment. Silane materials were often used for coupling with silica-based ceramics through the formation of a chemical covalent bond to obtain a chemical bond between resin and zirconia, which have silica-free and relatively nonpolar surfaces. They are chemically much more stable than silica-based ceramics, and thus traditional silane chemistry is not usually effective for zirconia (41).

Evaluating the mode of failure of specimens is important to demonstrate the quality of the bond to treated zirconium and composite resins. In this study, the tested specimens exhibited adhesive failure with the Ultradent and Single Bond repaired specimens, indicating that the Single Bond adhesive and Ultradent repaired specimens obtained a weak bond with the composite. As in previous studies, a higher mean SBS value is related to the predominance of mixed failure modes (45–46).

None of the repair methods resulted in cohesive failures in the zirconia specimens. This may be due to the effect of thermocycling on the bond between zirconia and composite resin.

No significant difference was observed in the mode of bond failure of the Bisco, Ultradent, and Clearfil repair systems. This result may be related to the presence of MDP, which increases the bond between zirconia and composite resin.

This study has the following limitations: the number of thermal cycles was limited, only one surface roughness method was investigated, and the experimental device can not fully simulate the oral environment. Further studies with higher number thermal cycles and those focusing on other types of surface roughness should be performed to provide more reliable information about repair systems.

Conclusion

Within the limitations of the present experimental study, the three repair systems, namely Ivoclar, Clearfil, and Bisco, could be used effectively for repairing chipped veneered porcelain for zirconia infrastructures. The observed failure modes indicates that Ivoclar, Clearfil, and Bisco repair systems could have advantages over others.

Türkçe Özet: *Beş farklı porselen tamir sisteminin Zirkonya alt yapılara bağlanma dayanımının karşılaştırılması. Amaç: Bu çalışmanın amacı, termal siklus sonrası beş farklı porselen tamir sisteminin kompozit ve zirkonya altyapıları arasındaki bağlanma dayanımı üzerindeki etkisini ve meydana gelen ayrılma tiplerini araştırmaktır. Gereç ve Yöntem: Disk şeklinde oluşturulmuş örnekler (n=50), Z'den yapıldı, tamir sistemi tipine göre beş alt gruba (n=10) ayrıldı. Herbir tamir sistemi zirkonyum numunelerine uygulandı ve onarım için hibrit kompozit kullanıldı. Tüm grupların bağlanma dayanımı testleri, termalsiklüs sonrasında Universal test makinesi kullanılarak gerçekleştirildi. Bulgular: Zirkonya tamirinde Single bond tamir sistemi hariç diğer tamir sistemlerinde anlamlı bir farklılık belirlenmedi. Single bond alt yapıların tamirinde en zayıf olarak bulunmuştur. Zirkonya grupları için en yüksek ve en düşük ortalama bağlanma dayanımı değerleri sırasıyla 18.91 MPa ve 3.63 MPa olarak ölçülmüştür. Sonuç: Zirkonya tamirinde üç tamir sisteminin (Ivoclar, Clearfil ve Bisco), Single bond ve Ultradent tamir sistemine göre daha etkili olduğu saptanmış ve ayrılma tipleri mixed ve adeziv olduğu görülmüştür. Anahtar kelimeler: Tamir sistemi; zirkonya; bağlanma dayanımı; adeziv sistem; ayrılma tipleri.*

Ethics Committee Approval: Not required.

Informed Consent: Not required.

Peer-review: Externally peer-reviewed.

Author contributions: SA, FE, and MÇG designed the study. SA, FE, and MÇG generated data for the study. SA, FE, and MÇG gathered data. SA, FE, and MÇG analyzed the data. SA, FE, and MÇG wrote the majority of the original draft of the paper. SA, FE, and MÇG wrote the manuscript. All authors approved the final version of this paper.

Conflict of Interest: The authors declared that they have no conflict of interest.

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

References

1. Kelsey WP 3rd, Latta MA, Stanislav CM, Shaddy RS Comparison of composite resin-to-porcelain bond strength with three adhesives. Gen Dent 2000;48:418-21. PMID: 11199616
2. Tulunoglu IF, Beydemir B. Resin shear strength to porcelain and a base metal alloy using two polymerization schemes. J Prosthet Dent 2000;83:181-6. [CrossRef]
3. Sced IR, McLean JW. The strength of metal/ceramic bonds with base metals containing chromium. A preliminary report. Br Dent J 1972;132:232-4. [CrossRef]
4. Prado RA, Panzeri H, Fernandes Neto AJ, Neves FD, Silva MR, Mendonca G Shear bond strength of dental porcelains to nickel-chromium alloys. Braz Dent J 2005;16:202-6. [CrossRef]

5. Ikemura K, Tanaka H, Fujii T et al. Development of a new single-bottle multi-purpose primer for bonding to dental porcelain, alumina, zirconia, and dental gold alloy. Dent Mater J 2011; 30:478-84. [CrossRef]
6. Yavuz T, Dilber E, Kara HB et al. Effects of different surface treatments on shear bond strength in two different ceramic systems. Lasers Med Sci 2013;28:1233-39. [CrossRef]
7. Lee SJ, Cheong CW, Wright RF, et al. Bond strength of the porcelain repair system to all-ceramic copings and porcelain. J Prosthodont 2014;23:112-6. [CrossRef]
8. Della Bona A, Mecholsky JJ, Jr, Barrett AA, et al. Characterization of glass-infiltrated alumina-based ceramics. Dent Mater 2008;24:1568-74. [CrossRef]
9. Kirmali O, Kapdan A, Harorli OT, Barutcugil C, Ozarslan MM. Efficacy of ceramic repair material on the bond strength of composite resin to zirconia ceramic. Acta Odontol Scand 2015;73:28-32. [CrossRef]
10. Gordon SR, Lloyd PM Fixed prosthodontics in the elderly population. Life expectancy of fixed restorations, failures, and retreatment methods. Dent Clin North Am 1992;36:783-95.
11. Walton JN, Gardner FM, Agar JR. A survey of crown and fixed partial denture failures: length of service and reasons for replacement. J Prosthet Dent 1986;56:416-21. [CrossRef]
12. Leibrock A, Degenhart M, Behr M, Rosentritt M, Handel G. In vitro study of the effect of thermo- and loadcycling on the bond strength of porcelain repair systems. J Oral Rehabil 1999;26:130-7. [CrossRef]
13. Ozcan M. Fracture reasons in ceramic-fused-to-metal restorations. J Oral Rehabil 2003;30:265-9. [CrossRef]
14. Casucci A, Monticelli F, Goracci C, et al. Effect of surface pre-treatments on the zirconia ceramic-resin cement microtensile bond strength. Dent Mater 2011 Oct;27(10):1024-30. [CrossRef]
15. Della Bona A, Kelly JR. The clinical success of all-ceramic restorations. J Am Dent Assoc 2008;139:8-13. [CrossRef]
16. Burke FJ. Repair of metal-ceramic restorations using an abrasive silica-impregnating technique: two case reports. Dent Update 2002;29:398-402. [CrossRef]
17. dos Santos JG, Fonseca RG, Adabo GL, et al. Shear bond strength of metal-ceramic repair systems. J Prosthet Dent 2006;96:165-73. [CrossRef]
18. Kim BK, Bae HE, Shim JS, et al. The influence of ceramic surface treatments on the tensile bond strength of composite resin to all-ceramic coping materials. J Prosthet Dent 2006;96:165-73.
19. Ozcan M, van der Sleen JM, Kurunmaki H, et al. Comparison of repair methods for ceramic-fused-to-metal crowns. J Prosthodont 2006;15:283-8. [CrossRef]
20. Kimmich M. Stappert CF. Intraoral treatment of veneering porcelain chipping of fixed dental restorations: a review and clinical application. J Am Dent Assoc 2013;144:31-44. [CrossRef]
21. Yoo JY, Yoon HI, Park JM, Park EJ. Porcelain repair - Influence of different systems and surface treatments on resin bond strength. J Adv Prosthodont 2015;7:343-8. [CrossRef]
22. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. J Dent 1999;27:89-99. [CrossRef]
23. Dündar M, Ozcan M, Gökçe B, Cömlekoğlu E, Leite F, Valandro LF. Comparison of two bond strength testing methodologies for bilayered all-ceramics. Dent Mater 2007;23:630-6. [CrossRef]
24. Hadavi F, Hey JH, Ambrose ER, Louie PW, Shinkewski DJ. The effect of dentin primer on the shear bond strength between composite resin and enamel. Oper Dent 1993;18:61-5.
25. Schneider, W. Powers, J.M. & T Pierpoint, H.P. Bond strength of composites to etched and silica coated porcelain fusing alloys. Dent Mater 1992;8:211-5. [CrossRef]
26. Matsumara H, Yanagida H, Tanoue N, Atsuta M, Shimoe S. Shear bond strength of resin composite veneering material to gold alloy with varying metal surface preparations. J Prosthet Dent 2001;86:315-9. [CrossRef]
27. Kocaagaoglu HH, Gürbulak A. An assessment of shear bond strength between ceramic repair systems and different ceramic infrastructures. Scanning 2015;37:300-5. [CrossRef]
28. Ohkuma K, K.azama M, Ogura H. The grinding efficiency by diamond points developed for yttria partially stabilized zirconia. Dent Mater J 2011;30:511-6. [CrossRef]
29. Barragan G, Chasquiera F, Arantes-Olivera S. Portugal J. Ceramic repair: influence of chemical and mechanical surface conditioning on adhesion to zirconia. Oral Health Dent Manag 2014;13:155-8.
30. Han IN, Kang DW, Chung CH, Choe HC, Kyoung M. Effect of various intraoral repair systems on the shear bond strength of composite resin to zirconia. J Adv Prosthodont 2013;5:248-55. [CrossRef]
31. Kocaagaoglu H, Manav T, Albayrak H. In Vitro Comparison of the Bond Strength between Ceramic Repair Systems and Ceramic Materials and Evaluation of the Wettability. J Prosthodont 2017;26:238-43. [CrossRef]
32. Tanaka R, Fujishima A, Shibata Y, Manabe A, Miyazaki T. Cooperation of phosphate monomer and silica modification on Zirconia. J Dent Res 2008;87:666-70. [CrossRef]
33. Magne P, Paranhos MP, Burnett LH Jr. New Zirconia primer improves bond strength of resin-based cements.Dent Mater 2010;26:345-52. [CrossRef]
34. Cura C, Ozcan M, Isik G, Saracoglu A. Comparison of alternative adhesive cementation concepts for Zirconia ceramic: Glaze layer vs Zirconia primer. J Adhes Dent 2012;14:75-82.
35. Koizumi H, Nakayama D, Komine F, Blatz MB, Matsumura H Bonding of resin-based luting cements to Zirconia with and without the use of ceramic priming agents. J Adhes Dent 2012;14:385-92.
36. Attia A, Kern M. Long-term resin bonding to Zirconia ceramic with a new universal primer. J Prosthet Dent 2011;106:319-27. [CrossRef]
37. Ural C, Külünk T, Külünk S, Kurt M, Baba S. Determination of resin bond strength to, Zirconia ceramic surface using different primers. Acta Odontol Scand 2011;69:48-53. [CrossRef]
38. Kitayama S, Nikaido T, Takahashi R, Zhu L, Ikeda M, Foxton RM, Sadr A, Tagami J. Effect of primer treatment on bonding of resin cements to Zirconia ceramic. Dent Mater 2010;26:426-32. [CrossRef]
39. Lehmann F, Kern M. Durability of resin bonding to zirconia ceramic using different primers. J Adhes Dent 2009;11:479-83.
40. P.C. Pott, M. Stiesch, M. Eisenburger, Influence of artificial aging on the shear bond strength of zirconiacomposite interfaces after pretreatment with new 10-MDP adhesive systems. Journal of Dental Materials and Techniques 2018;10:308-14. [CrossRef]
41. Lindgren J, Smeds J, Sjögren G. The effect of surface treatments and aging in water on bond strength to Zirconia. Oper Dent 2008;33:675-81. [CrossRef]
42. Kern M, Barloi A, Yang B. Surface conditioning influences Zirconia ceramic bonding. J Dent Res 2009;88:817-22. [CrossRef]
43. Akgungor G, Sen D, Aydin M. Influence of different surface treatments on the short-term bond strength and durability between a Zirconia post and a composite resin core material. J Prosthet Dent 2008 May;99:388-99. [CrossRef]
44. Thompson JY, Stoner BR, Piascik JR, Smith R. Adhesion/cementation to Zirconia and other non-silicate ceramics: Where are we now? Dent. Mater 2011;27:71-82. [CrossRef]
45. Attia A, Lehmann F, Kern M. Influence of surface conditioning and cleaning methods on resin bonding to zirconia ceramic. Dent Mater 2011; 27:207-13. [CrossRef]
46. Valandro LF, Ozcan M, Amaral R, Vanderlei A, Bottino MA. Effect of testing methods on the bond strength of resin to zirconia-alumina ceramic: microtensile versus shear test. Dent Mater J 2008 Nov;27:849-55. [CrossRef]

eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2022; 56(2): 61-66

Original research

The effects of reinforcement with nanoparticles of polyetheretherketone, zirconium oxide and its mixture on flexural strength of PMMA resin

Deepali Barapatre[1], Surabhi Somkuwar[2], Sunil Kumar Mishra[3], Ramesh Chowdhary[4]

Purpose

Polymethylmethacrylate denture bases are prone to fracture, so reinforcement of dentures with nanoparticles is required to overcome these challenges. This *in-vitro* study was done to assess the effect of reinforcement with nanoparticles of polyetheretherketone (PEEK), zirconium oxide (ZrO_2) and its mixture on flexural strength of polymethylmeythacrylate resin.

Materials and Methods

A total of 60 acrylic resin specimens measuring 65 mm × 10 mm × 2.5 mm were fabricated. The specimens were divided in to fifteen specimens in each group [control group (C), 3wt% PEEK group (P), 3wt% zirconia group (Z), and hybrid reinforcement of 1.5wt% PEEK and 1.5wt% ZrO_2 group (P-Z)]. The flexural strength of the specimens was evaluated using a three-point bending test on a universal testing machine. The statistical analysis was done using one-way analysis of variance (ANOVA), and the intergroup comparison was done using Tukey's *post hoc* analysis.

Results

The mean flexural strength was maximum in group P-Z (98.73MPa) followed by group P (86.22 MPa) and group Z (84.48 MPa). The mean flexural strength was least in the control group (74.86MPa). One-way ANOVA revealed a highly significant ($P<0.01$) difference among the groups. Pairwise comparison among groups showed a significant difference ($P<0.05$) among all the groups except in between groups P and Z where no significant difference was found ($P=0.406$).

Conclusion

Hybrid reinforced PEEK and zirconia could be used as an effective reinforcement material for denture base resin. The hybrid PEEK and zirconia reinforced resin can be an alternative treatment option in patients with heavy occlusal forces and for patients who have previous experience of multiple denture fractures.

Keywords: *Flexural strength, nanoparticles, polymethylmethacrylate, polyetheretherketone, zirconia*

Introduction

Polymethylmeythacrylate (PMMA) contributes up to 95% for the fabrication of removable dental prosthesis, due to its optical properties, biocompatibility, and aesthetics (1,2). However, significant issues still exist, which need to be addressed to improve the properties of PMMA for fabrication of dentures. PMMA denture bases are more prone to fracture due to stress concentration at the frenum notch, in rugae areas, in denture base regions with scratches, and under heavy masticatory forces (3-5).

Two methods were recommended to prevent the denture base fracture, one is by reinforcement of the denture base material and the oth-

ORCID IDs of the authors: D.B. 0000-0001-5749-0627; S.S. 0000-0001-5387-9010; S.K.M. 0000-0003-4844-1844; R.C. 0000-0002-3254-741X

[1]Department of Prosthodontics, People's College of Dental Sciences and Research Centre, Bhopal, Madhya Pradesh, India

[2]Department of Dentistry, All India Institute of Medical Sciences, Raipur, Chhattisgarh, India

[3]Department of Prosthodontics, Rama Dental College Hospital and Research Centre, Kanpur, Uttar Pradesh, India

[4]Department of Prosthodontics, Rajarajeswari Dental College & Hospital, Bengaluru, Karnataka, India

Corresponding Author: Sunil Kumar Mishra

E-mail: sunilmsr200@yahoo.co.in

Received: 28 March 2021
Revised: 30 June 2021
Accepted: 16 July 2021

DOI: 10.26650/eor.2022904564

How to cite: *Barapatre D, Somkuwar S, Mishra SK, Chowdhary R. The effects of reinforcement with nanoparticles of polyetheretherketone, zirconium oxide and its mixture on flexural strength of PMMA resin. Eur Oral Res 2022; 56(2): 61-66. DOI: 10.26650/eor.2022904564*

er is by reducing the stress concentration in the midline of the denture base (6). Various denture base designs/ techniques have advocated to decrease the stresses at the midline, but this usually increases the denture base thickness with decrease in the tongue space and thus influences the speech (7). Incorporation of nanoparticles to increase the strength of the denture bases surely emerge as a better treatment option.

Numerous endeavours seemed to be attempted in the past to enhance the mechanical properties of the acrylic resins by incorporating different strengthening materials: metal fillers, metals, carbon fibres, aramid fibres, glass fibres and ultra-high molecular weight polyethylene (8). Although the incorporation of fibres improves the flexural strength, increased fibre content generally decreases the surface hardness without much increase in strength (9-11).The expansion of metal fillers increases the compressive strength and thermal conductivity but compromises the esthetics and decreases the tensile strength (12).

For the past few years, zirconia has been used to strengthen the denture bases. Zirconia is a white crystalline dioxide of zirconium, with a flexural strength of 1666 MPa and having a modulus of elasticity like steel (13). Zirconia incorporated in dental materials has enhanced the mechanical properties of the dental materials with better esthetics (14-16). In recent years, polyetheretherketone (PEEK), a semi-crystalline linear polycyclic aromatic polymer, is used frequently in dentistry (17,18). PEEK is non hypersensitive and has low plaque affinity, with a flexural modulus of 140-170 MPa (18,19).Young's modulus and tensile properties of PEEK are similar to human bone, enamel and dentin (20,21). PEEK material is one of the better esthetic material utilized for the manufacture of removable partial dentures.

The present study was aimed to enhance the flexural strength of denture base resin by reinforcing it with PEEK and zirconia. Currently, no literature is available utilizing the hybrid reinforcement of PEEK and zirconia in acrylic denture base resin. This in vitro study was done to evaluate the flexural strength of PMMA denture base resin reinforced with 3wt% PEEK, 3wt% Zirconium oxide (ZrO_2) and in combination with 1.5wt% PEEK and 1.5wt% ZrO_2. The null hypothesis in the study was that there would be no difference in flexural strength of reinforced denture base resin with 3wt% PEEK, 3wt% $ZrO_2$and with a mixture of both 1.5wt% PEEK and 1.5wt% $ZrO_2$when compared to non-reinforced denture base resin.

Materials and methods

This in vitro study was done in the Prosthodontics Department with technological aid from the Central Institute of Plastics Engineering and Technology (Bhopal, India) and the Centre for Scientific Research and Development (Bhopal, India). A total of sixty specimens were made, with each group containing 15 specimens. The specimens were broadly divided into two groups: n=15 control group (C) and n=45 experimental groups (E). The experimental group is further divided into 3 subgroups with n=15 specimens each (Figure 1).

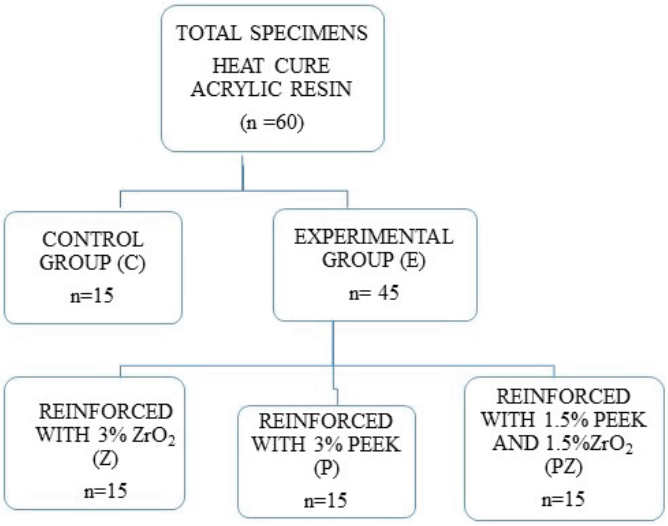


Figure 1. *Flow chart depicting distribution of specimens.*

Specimen fabrication

Wax specimens with dimensions of (65mm length x 10mm width x 2.5 mm thickness) were fabricated in a hard plastic mold according to American Dental Association specifications No.12 (Figure 2) (22).

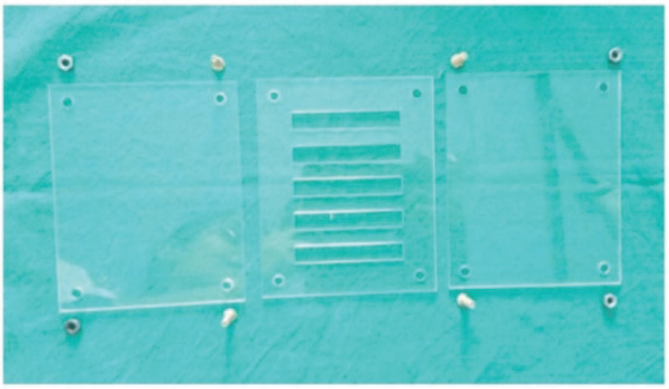


Figure 2. *The three piece standardized mold.*

The middle part of the mold was assembled over the lower part and petroleum jelly (Unilever, Mumbai, India) was applied. The mold was filled with the softened modelling wax (DPI, Mumbai, India). The cover plate was positioned in place and tightened with the screws to eliminate the extra wax. After some times, as the wax solidifies, the cover plate was unscrewed and the surplus wax was eliminated with a Bard Parker blade (Sigma Aldrich, New Delhi, India). The wax specimens were retrieved from the mold. The wax specimens, which were uniform in all dimensions, were taken for flasking and distorted specimens were eliminated. The specimens were invested in dental stone (Kalrock, Kalabhai, Mumbai, India) in flasks and allowed to set for 1h (Figure 3).

The flasks were kept in the dewaxing unit for 8 min and then opened and any residual wax was flushed by spraying with hot water. The mold was coated with separating medium (Coe-Sep, GCAcro-Sep, Europe).The required amount of PMMA, ZrO_2 and PEEK required to be mixed with acrylic resin was measured with an electronic balance having precision of up to three decimal places.

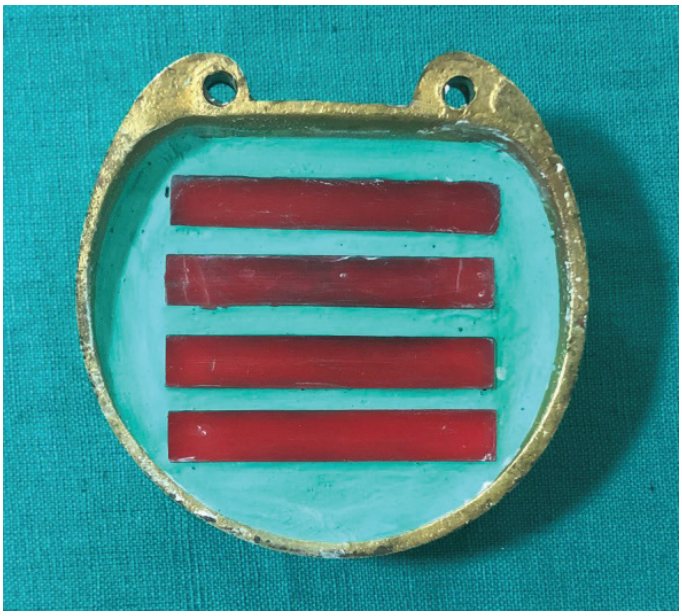


Figure 3. *Wax specimen positioned in the mold.*

Control group specimens

Control group specimens were fabricated with heat cure PMMA resin(Trevalon HI, Dentsply, Mumbai, India) incorporated in the ratio of 21 g polymer:10 ml monomer.

Experimental group specimens

PEEK group (P) specimens were fabricated with 3wt% PEEK (Vivtrex PEEK, Padmini Innovative Marketing Solution Pvt. Ltd. Mumbai, India)in ratio of 0.630g PEEK:20.370g polymer:10 ml monomer. Zirconia group (Z) specimens were fabricated with 3wt% ZrO_2 powder(Yttria stabilized zirconia nanopowder, Nanosheel Creating Miracles in black, Willmington DE, USA) in a ratio of 0.630g ZrO_2:20.370g polymer:10 ml monomer. For specimen fabrication of a combination group of PEEK and ZrO_2 (P-Z), 1.5wt% PEEK and 1.5 % ZrO_2 powder in a ratio of 0.315g PEEK:0.315g ZrO_2:20.370g polymer:10 ml monomer was used (Figure 4). A uniform mixture of the PEEK/ZrO_2/combinations within the acrylic powder was obtained with a blender running at a speed of 400 rpm for 30 min.

Figure 4. *Zirconium oxide and PEEK powder.*

Processing of specimens

Specimens were packed in the mold in the dough stage and the flask closed together. The packed flasks were kept under a hydraulic press (Mestra 48150 Sondika-Bilbao, Spain) applying a pressure of 14MPa for 30min. Conventional heatcure polymerization procedure was carried out for these packed specimens under a water bath for 9 h [(7 h/74 °C (±3°C) followed by 2 h/95°C(±3°C)]. After completion of the curing cycle, flasks were kept for 30min at room temperature for cooling, followed by cooling for 15mins under running tap water. The flasks were opened and specimens were retrieved. Finishing of specimens was done followed by polishing with silicon carbide paper of different grids (1000, 800, and 600 coarseness) (Figure 5). All the specimens were stored in an incubator containing distilled water for 48h at 37°C ± 1°C. To check the uniform dimensional accuracy in all the specimens, digital vernier calliper was used to measure at three different areas with a tolerance of not more than 0.2mm dimensional discrepancy.

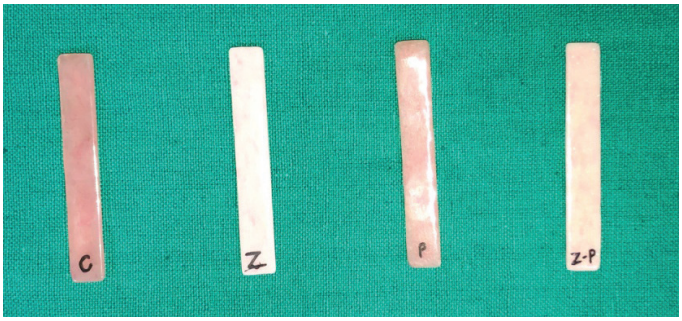


Figure 5. *Fabricated specimens.*

Three-point bending test

The specimens were placed under universal testing machine (Instron Corporation, Canton, MA, USA) (Figure 6) for 3-point bending test and flexural strength was evaluated at a crosshead speed of 2 mm/min. The fracture load (peak load)

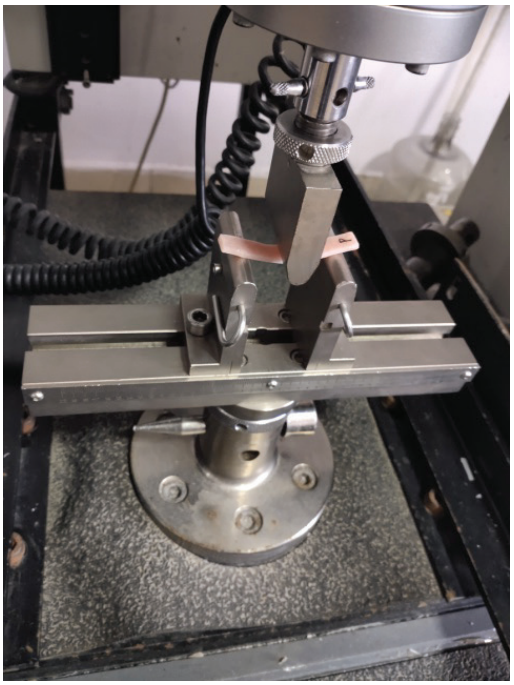


Figure 6. *Specimen under 3-point bending test.*

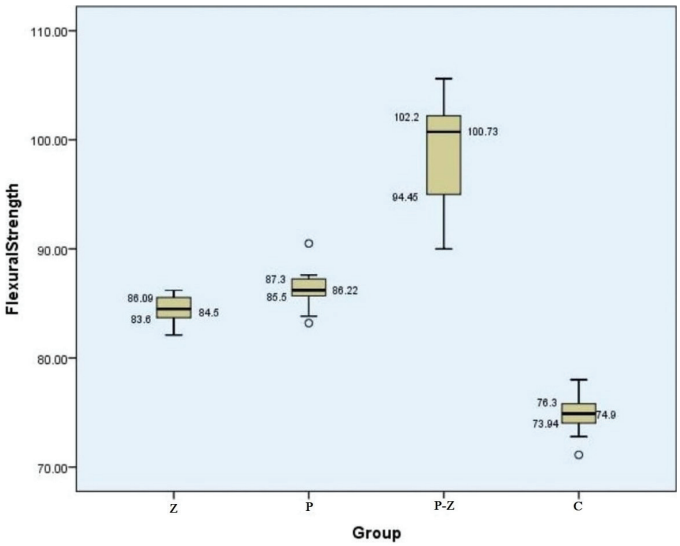


Figure 7. *Box plot showing flexural strength at maximum load of samples in different groups.*

for each specimen was evaluated and converted to flexural strength by using the formula *S* = 3PL/2bd Where *S*=flexural strength (N/mm2); P=load at fracture; L= distance between jig supports; b =specimen width; d=specimen thickness.

Statistical analysis

The data obtained was subjected to statistical analysis using Statistical Package for the Social Sciences (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk,NY:IBM Corp.).The statistical analysis was done using one-way analysis of variance (ANOVA), and the inter-group comparison was done using Tukey's *post hoc* analysis. A P-value<0.05 was considered statistically significant. The confidence interval was set at 95%.

Results

The mean flexural strength of the control group and experimental groups were presented in Table 1. The mean flexural strength of the experiment groups was significantly higher (P<0.05) than the control group. The mean flexural strength was maximum with a mixture of 1.5wt% PEEK and 1.5wt% ZrO_2 (98.73MPa) followed by 3% PEEK (86.22 MPa) and 3%ZrO_2 (84.48 MPa). The mean flexural strength was least in the control group (74.86MPa) (Fig 7). One-way ANOVA revealed a highly significant (P<0.01) difference among the groups. Pairwise comparison among groups showed a significant difference (P<0.05) among all the groups except in between the 3% PEEK group and 3% zirconia group, where no significant difference was found (P=0.406) (Table 1).

Discussion

The null hypothesis was rejected. Polymethylmethacrylate dentures are vulnerable to fracture while use or when accidentally dropped onto any hard surface due to their flexural fatigue on a time (9). Flexural fatigue generally happens due to continuous flexing of dentures which leads to the development of microcracks in the stress concentration area. Midline cracks are a typical issue for patients with maxillary complete dentures, due to cyclic disfigurement resulting in flexural fatigue (23). Despite the recent trend of incorporating ceramic fillers and composite materials into denture base resins, it is required to understand the effects of hybrid reinforcement of PEEK and zirconia in denture base resins. Muhsin *et al.*(24) determined the mechanical properties of PEEK polymer when used as a denture material in their study and found PEEK material to be a resistant material to notch concentration. They stated that if PEEK material is used for denture frameworks having notches at labial or buccal frenum, in these conditions too they are less prone to fracture. When used in elastic region PEEK has increased tensile strength with less plastic deformation compared to PMMA. In the present study, an increase of flexural strength (86.2MPa) by 15.17% was present with PMMA filled with PEEK filler which was more compared to the control group (74.8 MPa). PEEK can be advantageous in reducing stress concentration at notches for labial or buccal frenum, if incorporated as nanoparticles in denture bases.

Zidan *et al.*(25) had analysed the flexural strength of high impact heat-polymerised PMMA resin incorporating various concentrations of ZrO_2 nanoparticles (1.5%, 3%, 5%, 7%, and 10wt%).They found that the inclusion of ZrO_2 nanoparticles in PMMA resin had gradually increases the flexural strength up to 3 wt% and after that the flexural strength decreases at higher concentrations when compared to the control group. There was a 15% significant increase in flexural strength and it was highest in the group having 3 wt% ZrO_2 (83.5 MPa) when compared to the control group (72.4 MPa). Filler concentration at 3wt% seems to increase the flexural strength. Specimens with high filler concentration causes more filler-to-filler interactions compared to matrix-to-filler interactions and forms an agglomeration causing non uniform stress distribution due to forming a point of stress concentration (26). In the present study, a similar result was found with an increase of 12.85% in flexural strength when PMMA was strengthened with 3wt % ZrO_2 (84.4 MPa) in comparison to

Table 1: *One way ANOVA for flexural strength of different groups*.

Group	n	Mean (MPa)	SD	F ratio	P value	Tukey's post hoc analysis
Control group (C)	15	74.86	1.74	46.868	<0.0001	P_1<0.05*
3wt% Zirconia group (Z)	15	84.48	1.34			P_2<0.05*
3wt% PEEK group (P)	15	86.22	1.78			P_3<0.05*
Hybrid reinforcement of 1.5wt% zirconia 1.5wt% PEEK group (P-Z)	15	98.73	4.97			P_4=406 P_5<0.05* P_6<0.05*

*P value<0.05 was considered statistically significant. ANOVA=Analysis of variance; P1= between group C and group Z; P2= between group C and group P; P3= between group C and group P-Z; P4= between group Z and group P; P5= between group Z and group P-Z; P6= between group P and group P-Z

the control group (74.86 MPa) and the difference obtained was statistically significant. Zirconium oxide as nanoparticles has a large interfacial area which enhances the contact points in between the PMMA and ZrO_2, thus promotes additional mechanical interlocking and with more flexibility (27).

Sirandoni *et al*. (28) in a 3D finite element analysis, evaluated the biomechanical properties of various framework materials used for fabrication of implant supported mandibular fixed prosthesis. They favoured zirconia material over PEEK and PMMA as a framework material. Muhsin *et al*.(24) found in their study that PEEK had a higher tensile strength than PMMA and could be preferred for fabrication of denture in the near future. Thus, we reinforced both ZrO_2 and PEEK into PMMA to incorporate the qualities of both the materials. Gad *et al*.(29) in their study reinforced the PMMA resin with ZrO_2 nanoparticles and glass fibers (GFs) in different concentrations and found increased flexural strength of group with 2.5% ZrO_2 + 2.5% GFs by45% compared to that of non-reinforced PMMA. The increase in flexural strength was possible because of the synergistic effect of ZrO_2 and GFs. In present the study, the hybrid reinforcement of PEEK and ZrO_2(1.5wt% PEEK and 1.5wt% ZrO_2) in PMMA was done and a 31.88% increase in flexural strength (98.73MPa) was found compared to non-reinforced PMMA. In the present study maximum flexural strength found in the hybrid group which may be due to the synergistic effect of PEEK and ZrO_2.

In this study, to enhance the mechanical bonding of the PEEK and zirconia with PMMA, the powders were mixed with a blender running at a speed of 400 rpm for 30 min. This process helps in achieving an even distribution of the PEEK/ZrO_2 combinations within the acrylic powder. This helps in better bonding and reducing the agglomeration tendency in the mix and thus helps in reducing the points of stress concentration (29).

No difficulty was encountered during the finishing and polishing of the specimens and a well-polished surface was obtained with the specimens of all the groups. The shade obtained with the ZrO_2 group has a more whitish appearance when compared to other groups. The shade obtained with the PEEK group was almost similar to the control group. The shade obtained with the PEEK-ZrO_2 group was slightly whiter compared to the control group but seems esthetically acceptable.

One of the basic requirements for a successful denture is flexural strength, which should be enough to prevent catastrophic failure under loading (20,30,31). A completely polymerized acrylic resin has better mechanical properties (32,33).The increased flexural strength indicates the quality of polymerization and suggests that the denture can resist the applied forces. In the present study, the overall result showed that the flexural strength of hybrid reinforced PEEK and zirconium oxide with denture base material has higher flexural strength than PEEK and zirconia individually with denture base material. The hybrid reinforcement might be helpful in bruxism patients, and in patients with resorbed ridge who are more prone to denture fractures. In patients with prominent anterior maxilla, the hybrid dentures can be given with thinner flanges as an alternative to flangeless denture with acceptable esthetics and at an affordable cost.

The limitation of the present study is that the study is *in-vitro* which is commonly performed to predict the behavior of materials in the clinical setting, but it would have provided further information if thermo-cycling would have been done to better simulate the oral conditions. Further research simulating the oral conditions is required to investigate the performance of this material in present and other possible combinations to find out whether they had any effect on other mechanical and physical properties of the denture bases. Scanning electron microscope study should be done to find the surface characteristics, distribution of nanoparticles in the mixture and to check for porosities and formation of agglomerates at the fracture site.

Conclusion

Hybrid reinforced PEEK and zirconia could be used as an effective reinforcement material for denture base resin. Hybrid PEEK and zirconia reinforced resin can be an alternative treatment option in patients with heavy occlusal forces and for patients who have previous experience of multiple denture fractures. Further studies are required to test the performance of this combination in fatigue testing and cyclic loading to establish the result of the present study.

Türkçe Özet: *Polietereterketon, zirkonyum oksit ve karışımının nanoparçacıkları ile güçlendirmenin polimetilmeytakrilat reçinenin eğilme mukavemeti üzerindeki etkisi. Amaç: Polimetilmetakrilat protez kaideleri kırılmaya eğilimlidir, bu nedenle protezlerin nanoparçacıklarla güçlendirilmesi gerekebilir. Bu in vitro çalışma, polietereterketon (PEEK), zirkonyum oksit (ZrO2) ve karışımının nanoparçacıkları ile takviyenin polimetilmetakrilat reçinenin eğilme mukavemeti üzerindeki etkisini değerlendirmek için yapılmıştır. Gereç ve yöntemler: 65 mm × 10 mm × 2.5 mm ölçülerinde toplam 60 akrilik reçine numunesi üretildi. Örnekler her grupta on beş örneğe [kontrol grubu (C), ağırlıkça %3 PEEK grubu (P), ağırlıkça %3 zirkonya grubu (Z) ve ağırlıkça %1.5 PEEK ve ağırlıkça %1.5 ZrO2 grubu (P-Z) hibrit grup.)]. Numunelerin eğilme mukavemeti, evrensel test makinesinde üç nokta eğme testi kullanılarak değerlendirildi. İstatistiksel analiz, tek yönlü varyans analizi (ANOVA) kullanılarak yapıldı ve gruplar arası karşılaştırma, Tukey'nin post hoc analizi kullanılarak yapıldı. Bulgular: En yüksek ortalama eğilme mukavemeti grup P-Z'de (98.73 MPa), ardından grup P'de (86.22 MPa) ve grup Z'de (84.48 MPa) bulundu. En az ortalama eğilme mukavemeti kontrol grubundaydı (74.86MPa). Tek yönlü ANOVA, gruplar arasında anlamlı (P<0.01) bir fark ortaya koydu. Gruplar arasında ikili karşılaştırma, anlamlı bir farkın bulunmadığı P ve Z grupları dışında (P=0,406) tüm gruplar arasında anlamlı bir fark gösterdi (P<0,05). Sonuç: Hibrit takviyeli PEEK ve zirkonya, protez kaidesi reçinesi için etkili bir takviye materyali olarak kullanılabilir. Hibrit PEEK ve zirkonya ile güçlendirilmiş reçine, yüksek oklüzal kuvvetleri olan hastalarda ve daha önce çoklu protez kırığı deneyimi olan hastalarda alternatif bir tedavi seçeneği olabilir. Anahtar Kelimeler: eğilme mukavemeti, nanopartiküller, polimetilmetakrilat, polietereterketon, zirkonya*

Ethics Committee Approval: Not required.

Informed Consent: Not required.

Peer-review: Externally peer-reviewed.

Author contributions: DB, SS, SKM participated in designing the study. DB, SS, RC participated in generating the data for the study. DB, SKM participated in gathering the data for the study. DB, SKM, RC participated in the analysis of the data. DB, SS, SKM, RC wrote the majority of the original draft of the paper. DB, SS, SKM, RC participated in writing the paper. DB, SS, SKM have had access to all of the raw data of the study. DB, SKM, RC have reviewed the pertinent raw data on which the results and conclusions of this study are based. DB, SS, SKM, RC have approved the final version of this paper. SKM guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared that they have no conflict of interest.

Financial Disclosure: The authors declared that they did not receive financial support.

References

1. Tanoglu M, Ergun Y. Porous nanocomposites prepared from layered clay and PMMA [poly (methyl methacrylate)].Composites Part A: Appl Sci Manufact 2007;38:318-22. [CrossRef]
2. Gurbuz O, Unalan F, Dikbas I. Comparison of the transverse strength of six acrylic denture resins. OHDMBSC 2010;9:21-4.
3. Darbar UR, Huggett R, Harrison A. Denture fracture-A survey. Br Dent J 1994; 176:342-5. [CrossRef]
4. Peyton FA. History of resins in dentistry. Dent Clin North Am 1975;19:211-22.
5. Dixon DL, Breeding LC. The transverse strengths of three denture base resins reinforced with polyethylene fibres. J Prosthet Dent 1992;67:417-9. [CrossRef]
6. Kelly E. Fatigue failure in denture base polymers. J Prosthet Dent 1969;21:257-66. [CrossRef]
7. Yunus N, Rashid AA, Azmi LL, Abu-Hassan MI. Some flexural properties of a nylon denture base polymer. J Oral Rehabil 2005;32:65-71. [CrossRef]
8. Rodford R. The development of high impact strength denture-base materials. J Dent 1986;14:214-7. [CrossRef]
9. Jagger D, Harrison A, Jandt KD. The reinforcement of dentures. J Oral Rehabil 1999;26:185-94. [CrossRef]
10. Zappini G, Kammann A, Wachter W. Comparison of fracture tests of denture base materials. J Prosthet Dent 2003;90:578–85. [CrossRef]
11. Stafford GD, Bates JF, Huggett R, Handley RW. A review of the properties of some denture base polymers. J Dent 1980;8:292-306. [CrossRef]
12. Sehajpal SB, Sood VK. Effect of metal fillers on some physical properties of acrylic resin. J Prosthet Dent 1989;61:746-51. [CrossRef]
13. Vagkopoulou T, Koutayas SO, Koidis P, Strub JR. Zirconia in dentistry: Part 1. Discovering the nature of an upcoming bioceramic. Eur J Esthet Dent 2009;4:130-51.
14. Zuccari AG, Oshida Y, Moore BK. Reinforcement of acrylic resins for provisional fixed restorations. (Part I): Mechanical properties. Biomed Mater Eng 1997;7:327-43. [CrossRef]
15. Panyayong W, Oshida Y, Andres CJ, Barco TM, Brown DT, Hovijitra S. Reinforcement of acrylic resins for provisional fixed restorations. Part III: Effects of addition of titania and zirconia mixtures on some mechanical and physical properties. Biomed Mater Eng 2002;12:353-66.
16. Korkmaz T, Dogan A, Usanmaz A. Dynamic mechanical analysis of provisional resin materials reinforced by metal oxides. Biomed Mater Eng 2005;15:179-88.
17. Monich PR, Berti FV, Porto LM, Henriques B, de Oliveira APN, Fredel MC, *et al.* Physicochemical and biological assessment of PEEK composites embedding natural amorphous silica fibres for biomedical applications. Mater Sci Eng C Mater Biol Appl 2017;79:354-62. [CrossRef]
18. Rahmitasari F, Ishida Y, Kurahashi K, Matsuda T, Watanabe M, Ichikawa T. PEEK with reinforced materials and modifications for dental implant applications. Dent J (Basel) 2017;5:35. [CrossRef]
19. Skirbutis G, DzingutėA, Masiliūnaitė V, Šulcaitė G, Žilinskas J. A review of PEEK polymer's properties and its use in prosthodontics. Stomatologija 2017;19:19-23.
20. Zoidis P, Papathanasiou I, Polyzois G. The use of a modified poly ether ether ketone (PEEK) as an alternative framework material for removable dental prostheses. A clinical report. J Prosthet Dent 2015;25:580-4. [CrossRef]
21. Skirbutis G, Dzingutė A, Masiliūnaitė V, Šulcaitė G, Žilinskas J. A review of PEEK polymer's properties and its use in prosthodontics. Stomatologija 2017;19:19-23.
22. Revised American Dental Association specification no.12 for denture base polymers. J Am Dent Assoc 1975;90:451-8. [CrossRef]
23. Beyli MS, von Fraunhofer JA. An analysis of causes of fracture of acrylic resin dentures. J Prosthet Dent1981;46:238-41. [CrossRef]
24. Muhsin SA, Hatton PV, Johnson A, Sereno N, Wood DJ. Determination of polyetheretherketone (PEEK) mechanical properties as a denture material. Saudi Dent J 2019;31:382-91. [CrossRef]
25. Zidan S, Silikas N, Haider J, Alhotan A, Jahantigh J, Yates J. Evaluation of equivalent flexural strength for complete removable dentures made of zirconia-impregnated pmma nanocomposites. Materials 2020;13:2580. [CrossRef]
26. Kundie F, Azhari CH, Ahmad ZA. Effect of nano-and micro-alumina fillers on some properties of poly (methyl methacrylate) denture base composites. J Serb Chem Soc 2018;83:75-91. [CrossRef]
27. Gad MM, Abualsaud R, Rahoma A, Al-Thobity AM, Al-Abidi KS, Akhtar S. Effect of zirconium oxide nanoparticles addition on the optical and tensile properties of polymethyl methacrylate denture base material. Int J Nanomed 2018;13:283-92. [CrossRef]
28. Sirandoni D, Leal E, Weber B, Noritomi PY, Fuentes R, Borie E. Effect of different framework materials in implant-supported fixed mandibular prostheses: a finite element analysis. Int J Oral Maxillofac Implants 2019;34:e106-14. [CrossRef]
29. Gad MM, Al-Thobity AM, Rahoma A, Abualsaud R, Al-Harbi FA, Akhtar S. Reinforcement of PMMA denture base material with a mixture of ZrO_2 nanoparticles and glass fibers. Int J Dent 2019;2019:1-11. [CrossRef]
30. Oku JI. Impact properties of acrylic denture base resin. Part 1. A new method for determination of impact properties. Dent Mater J 1988;7:166-73. [CrossRef]
31. Neihart TR, Li SH, Flinton RJ. Measuring fracture toughness of high-impact poly(methyl methacrylate) with the short rod method. J Prosthet Dent 1988;60:249-53. [CrossRef]
32. Harrison A, Huggett R. Effect of the curing cycle on residual monomer levels of acrylic resin denture base polymers. J Dent 1992;20:370-4. [CrossRef]
33. Jagger RG. Effect of the curing cycle on some properties of a polymethylmethacrylate denture base material. J Oral Rehabil 1978;5:151-7. [CrossRef]

eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2022; 56(2): 67-73

Original research

Evaluation of the relationship between tooth decay and trabecular bone structure in pediatric patients using fractal analysis: a retrospective study

Dilara Nil Gunacar[1], **Sengul Merve Erbek**[2], **Sema Aydınoglu**[3], **Taha Emre Kose**[1]

Purpose

The movement of chewing affects the growth and development of the stomatognathic system. Tooth decay, which is known to have effects on chewing, can affect the jaw bone due to its indirect effect on the mechanical forces transmitted to the jaw bone. This study aimed to evaluate the relationship between dental caries and jawbone trabeculation during the growth and development processes in children using fractal dimension (FD) analysis.

Materials and Methods

A total of 120 patients were divided into three groups. The groups were determined as follows: group 1: 40 patients without deep dentin caries/apical rarefying osteitis, group 2: 40 patients with deep dentin caries/apical rarefying osteitis on the right or left sides, and group 3: 40 patients with deep dentin caries/apical rarefying osteitis on both the right and left side. Digital panoramic images of the selected patients were evaluated using FD analysis.

Results

There was no statistically significant difference in the FD analysis among the groups ($p>0.05$). Age and sex factors were not found statistically significant in the in-group evaluation ($p>0.05$). In group 3, FD values of the right condyle ($r= -0.42$, $p<0.05$), right ramus ($r= -0.37$, $p<0.05$) and left ramus ($r= -0.45$, $p<0.05$) were negatively correlated with age.

Conclusion

There is no relationship between tooth decay and trabeculation of the jawbone in children aged 8-13 years.

Keywords: *Bone, dental caries, fractals, mandible, radiology*

Introduction

Tooth decay is one of the most common public health problems in childhood. It may cause discomfort, pain, decreased quality of life, and changes in chewing patterns in children (1,2). Chewing is a developmental function that matures through experience. Childhood is very important for performing mastication skills. Proper chewing function stimulates the development of the maxilla and mandible (3).

It is known that individuals may have a preference for the chewing side to improve comfort and chewing efficiency (4). Changes in chewings pattern may be due to tooth decay, which causes pain and decreases the occlusal contact area. With the mechanical stimulus caused by chewing, pain in a decayed tooth decreases chewing performance and the maximum chewing force (2). Decerle *et al.* (5) reported that untreated dental caries decreased chewing performance in adults by reducing the inter-arch occlusal contact area. Barbosa *et al.* (6) reported that there was a

ORCID IDs of the authors: D.N.G. 0000-0002-9607-6362; S.M.E. 0000-0002-2160-4343; S.A. 0000-0003-1490-8645; T.E.K. 0000-0003-3601-0393

[1]*Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Recep Tayyip Erdoğan University, Rize, Turkiye*

[2]*Ordu Oral and Dental Health Center, Ordu, Turkiye*

[3]*Department of Pediatric Dentistry, Faculty of Dentistry, Recep Tayyip Erdoğan University, Rize, Turkiye*

Corresponding Author: Dilara Nil Gunacar

E-mail: dt.dilaranil@gmail.com

Received: 6 January 2021
Revised: 19 July 2021
Accepted: 25 July 2021

DOI: 10.26650/eor.2022854959

How to cite: *Gunacar DN, Erbek SM, Aydınoglu S, Kose TE. Evaluation of the relationship between tooth decay and trabecular bone structure in pediatric patients using fractal analysis: a retrospective study. Eur Oral Res 2022; 56(2): 67-73. DOI: 10.26650/eor.2022854959*

positive correlation between the number of decayed teeth and median particle size, as represented by the degree of fragmentation of a test food after chewing. The degree of fragmentation of the food was determined by sieving. An increase in the number of decayed teeth decreased chewing performance.

Changes in occlusal forces cause microscopic and macroscopic changes in jawbones. Trabecular bone architecture has a suitable structure for load-bearing functions (7). Trabecular bone is more determinant in evaluating changes in bone structure because it has a higher metabolic activity compared with cortical bone (8). Fractal dimension (FD) analysis measured on digital panoramic radiographs (DPRs) is a way to measure to determine early periodontal problems in the alveolar bone and mandibular trabecular architecture (9). The popularity of FD has increased in recent years, it offers features such as easy to access, providing objective data about trabecular structures, not being affected by variables such as radiologic density, and projection geometry (10,11). FD analysis can be performed using the existing DPR of patients without the need for extra imaging and materials (12).

Underlying peripheral sensorimotor pathways mature as oral motor skills mature in childhood (13). It is important to understand the effects of dental caries on the jawbone to ensure the correct growth and development of the stomatognathic system because the growth and development process adapts to functional models. The purpose of this study was to assess the relationship between dental caries and jawbone trabeculation using FD analysis in children in the growth and development periods. The null hypothesis was that there would be no difference among the non-carious group, the unilateral carious group, and the bilateral carious group in the mandibular trabecular FD values.

Materials and Methods

Ethical statement

This study has been reviewed and approved by the Recep Tayyip Erdoğan University Clinical Studies Ethics Committee (2020/127).

Patient selection

DPRs of systemically healthy patients aged 8-13 years who presented to Recep Tayyip Erdoğan University, Faculty of Dentistry Pediatric Dentistry Department between 01.2018 and 04.2020 were scanned retrospectively. To exclude changes that might occur in the bone and chewing pattern during tooth eruption, patients with first molars whose root development was completed and unerupted second molars were included in the study. Patients with disorders of temporomandibular joint, those exposed to trauma in the area to be measured, any systemic disease, who received orthodontic treatment in the last 2 years/had ongoing orthodontic treatment, parafunctional habits in their anamnesis, unilateral/bilateral cross-bite were not included in the study. Also, radiographs with errors that might affect the diagnostic capacity such as patient movement and positioning error were not included in the study.

Patients who met the inclusion criteria were divided into three groups according to the following conditions in their permanent first molar teeth:

-Patients without apical rarefying osteitis / deep dentin caries (the non-carious group) (Group 1),

-Patients with apical rarefying osteitis / deep dentin caries on the left or right sides (the unilateral carious group) (Group 2),

-Patients with apical rarefying osteitis / deep dentin caries on both the left and right side (the bilateral carious group) (Group 3),

Four hundred DPRs were investigated; 120 of the radiographs that met our inclusion criteria were included in the study. Forty eligible patients were randomly selected for each group, with equal numbers of boys and girls. DPRs of the patients were obtained at 66 kVp, 8 mA, 16.6 seconds using a Planmeca Promax 2D S2 device (Planmeca Oy; Helsinki, Finland).

Evaluation of Images using Fractal Dimension Analysis

Images were evaluated by a dentomaxillofacial radiologist (D.N.G.). DPRs were recorded in TIF (high-resolution option) format to ensure standardization of the images and adjusted to 2836 x 1500 pixels. The ImageJ (V.1.53) software (National Institutes of Health, Bethesda) bundled with 64-bit Java for Windows was used for the FD analysis of the images. FD analysis was performed on DPRs, which was transferred to the ImageJ program (National Institutes of Health, Bethesda), and three regions of interest (ROI) of 15 x 15 pixels were determined for each patient with the antegonial notch in the left and right hemi-mandible, the condyle, and in the center of the ramus (Figure 1).

Figure 1. *Selection of the ROIs on DPRs.*

The ROIs were evaluated by one dentomaxillofacial radiologist with 6 years of experience (D.N.G.). The copied ROI was blurred using the 'Gaussian Blur' filter. With this option, bright areas caused by changes in soft tissue and bone thickness became blurred and were removed from the original image. Then, using the "Make Binary" option, the image was converted to black and white and the borders of the trabecular structure and cortical bone were clarified. Image noise was reduced by using the 'Erode' option. With the "Dilate" option, the generations were extended and clarified. The "Invert" button makes the white areas were converted to black and the black areas to white. Thus, the borders of the trabecular bone became clear. Finally, by selecting the 'Skeletonize' option, the trabecular structure was converted into a skeleton structure format. Images were prepared for FD analysis. Using the "Fractal Box Counter," the measurements were divided into squares

of 2, 3, 4, 6, 8, 12, 16, 32, and 64 pixels. the total number of frames and the number of frames containing the trabecular structure were calculated for different dimensions. The number of frames containing the total number of frames and the trabecular structure were calculated for different dimensions. The values were transferred to a logarithmic scale automatically and the slope of the curve fitting the points on the graph gave the result of the FD measurement (Figure 2).

The kappa coefficient was used to calculate the intra-observer correlation coefficient. For this purpose, 20 patients were randomly re-measured 2 weeks later.

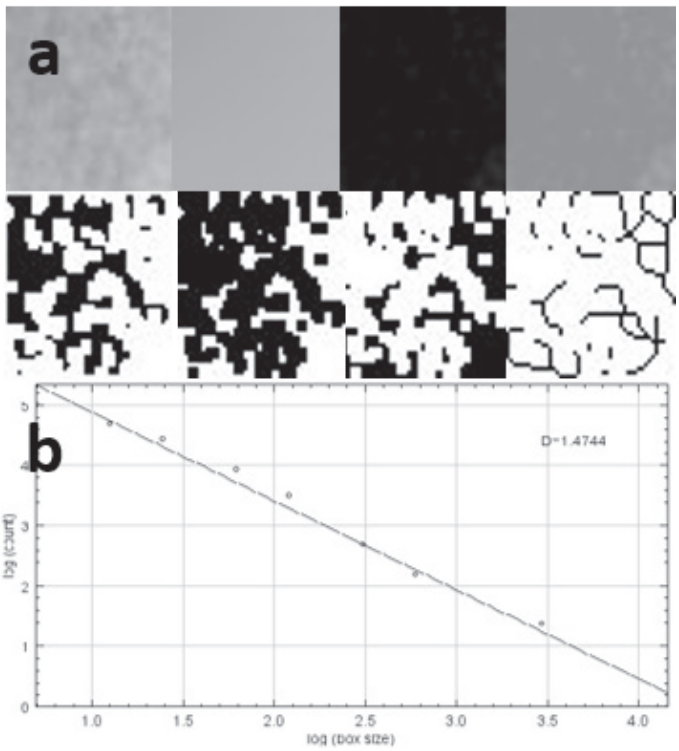


Figure 2. *Steps of FD analysis: Top row left to right respectively; cropped and duplicated ROI, gaussian blur, subtracted blurred image from the original image, addition of a gray value of 128 to each pixel location. Bottom row from left to right respectively; erosion, dilatation, inversion, skeletonization. b. FD analysis with the box-counting method.*

Statistical analysis

Post-hoc power analysis was performed with the G*Power 3.1.0 software package (Universitat Dusseldorf, Germany) to determine the number of patients to include in the study. For statistical analysis, the SPSS Statistics 23.0 (SPSS, Chicago, IL, USA) program was used. The age, sex, and distribution of the patients were analyzed using descriptive statistical methods. The suitability of the variables to normal distribution was evaluated using the Kolmogorov-Smirnov/Shapiro-Wilk tests. Mean and standard deviation were used for variables with normal distribution, and median and range values were given for variables that did not show normal distribution. The paired-samples t-test was used for measuring data independent groups with parametric distribution, and the independent samples t-test was used in independent groups. Data of non-parametric distributed dependent groups were assessed using the Wilcoxon test, and independent groups were evaluated using ANOVA and the Kruskal-Wallis test. The relationship between FD analysis and age was calculated using Spearman's correlation analysis. The statistical significance level was accepted as $p<0.05$.

Results

The null hypothesis was accepted. The post hoc power was calculated as 0.16 (noncentrality parameter: 1.42, critical F: 3.07, 1-b error probability: 0.83, effect size: 0.109). It was determined that 8 of the 120 patients were aged 9 years, 26 were aged 10 years, 32 were aged 11 years, 39 were aged 12 years, and 15 patients were aged 13 years. The mean ages of 60 female and 60 male patients were 11.20 ± 1.11 and 11.25 ± 1.14 years, respectively.

The relationship between sex and FD is shown in Table 1. The Total FD values were found to be the highest in the condylar region and the lowest in the gonial region. However, there was no significant difference between right, left, and total FD values and sex (Table 1). In Table 2, the relationships between group 1, group 2, and group 3 FD values are evaluated. No statistically significant difference was observed among the average FD values and the groups.

The correlations between the FD values and the age of patients in groups 1 and 3 are presented in Table 3. No re-

Table 1: *The relationship between gender and FD values of regions.*

ROI	Female			Male			Total			p
	Mean±SD	Med	(Min-Max)	Mean±SD	Med	(Min-Max)	Mean±SD	Med	(Min-Max)	
Right condyle	1.44±0.08	1.46	(1.14-1.56)	1.43±0.10	1.45	(1.20-1.79)	1.44±0.09	1.46	(1.14-1.79)	0.517[a]
Right gonial	1.37±0.09	1.36	(1.14-1.54)	1.36±0.12	1.38	(1.03-1.69)	1.37±0.11	1.37	(1.03-1.69)	0.705[b]
Right ramus	1.35±0.16	1.41	(1.03-1.56)	1.36±0.14	1.37	(1.04-1.59)	1.36±0.15	1.37	(1.03-1.59)	0.906[a]
Left condyle	1.43±0.10	1.46	(1.12-1.59)	1.42±0.09	1.42	(1.11-1.56)	1.43±0.10	1.43	(1.11-1.59)	0.715[a]
Left gonial	1.35±0.12	1.37	(1.09-1.59)	1.32± 0.12	1.33	(1.00-1.54)	1.34±0.12	1.34	(1.00-1.59)	0.125[b]
Left ramus	1.37±0.11	1.38	(1.05-1.56)	1.35± 0.13	1.38	(1.02-1.55)	1.36±0.12	1.38	(1.02-1.56)	0.446[b]
Total condyle	1.44±0.09	1.46	(1.12-1.59)	1.43± 0.09	1.44	(1.11-1.79)	1.43±0.09	1.45	(1.11-1.79)	0.399[a]
Total gonial	1.36±0.11	1.36	(1.09-1.59)	1.34± 0.13	1.34	(1.00-1.69)	1.35±0.12	1.36	(1.00-1.69)	0.164[b]
Total ramus	1.36±0.14	1.38	(1.03-1.56)	1.35± 0.13	1.37	(1.02-1.59)	1.36±0.14	1.38	(1.02-1.59)	0.692[a]

Med: Median; FD: Fractal dimension; SD: Standard deviation; Min: Minimum, Max: Maximum; a Mann-Whitney U; b Independent samples t-test

lationship was found between the FD values of group 1 and age. However, a negative correlation was found between FD values and age in group 3 for the right condyle (r= -0.42, p<0.05), right ramus (r= -0.37, p<0.05), and left ramus (r= -0.45, p<0.05).

The variability in the FD values of the study groups determined according to the presence of dentin caries is evaluated in Table 4. It was observed that the FD values of each group in the condyle area were higher than the other regions; however, no statistically significant relationship was found. In addition, no significant difference statistically was present among the right, left, and total FD values and sex. Intra-observer correlation coefficients were found to be excellent (k>0.75).

Discussion

Biologic changes occurring in hard tissue are affected by mechanical forces. One of the most important features of the internal structure of living bones is the ability to adapt to the mechanical forces to which they are exposed. Trabecular bone architecture is optimally structured for load-bearing function and bone grows in response to applied mechanical force (7). As with the entire skeletal system, trabecular and alveolar cortical bone also has a continuous remodeling cycle. Given that the occlusal forces generated during chewing are transmitted to the jawbones through the tooth, it is expected that trabecular bone tissue properties change in response to mechanical force. In our study, the effect of the presence of dental caries on the jawbones in children aged 8-13 years was evaluated retrospectively using FD analysis, which is an objective evaluation method.

Motor control of chewing is provided by inter-arch occlusal contact, the temporomandibular joint, dental pulp, and periodontal receptors (14,15). Accordingly, any situation that affects the tooth structure and position may affect the chewing system (5). Tooth decay is the most common oral health problem (2). If tooth decay is not treated, it can lead to pulpal and periapical infection and tooth loss. Kaya *et al*. (2) examined the relationship between chewing and tooth decay and reported that the presence of tooth decay led to a decrease in occlusal contacts due to cavitation formation and decreased chewing performance. De Morais *et al*. (16) reported that children with higher dmft/DMFT scores had larger median particle sizes, thus lesser chewing performance. Similarly, Su *et al*. (17) showed that there was a relationship between tooth decay and chewing performance and chewing cycles in preschool children. It is known that children can develop behaviors such as increased chewing time, a unilateral chewing pattern, refusing certain foods, and turning to softer foods in the presence of tooth decay (13).

FD is a mathematical analysis method with which irregular and complex body structures can be evaluated. FD analysis can be viewed as a measure of the disorder of many physi-

Table 2: *Comparisons of the study groups in terms of ROI values.*

ROI	Bilateral Carious			Non-Carious			Unilateral Carious			p value
	Mean FD±SD	Median	(Min-Max)	Mean FD ± SD	Median	(Min-Max)	Mean FD±SD	Median	(Min-Max)	
Right Condyle	1.43±0.09	1.45	(1.14-1.58)	1.45±0.07	1.46	(1.22-1.56)	1.43±0.11	1.46	(1.11-1.79)	0,661[a]
Right Gonial	1.36±0.10	1.36	(1.03-1.54)	1.37±0.10	1.37	(1.14-1.54)	1.34±0.11	1.33	(1.11-1.69)	0,655[b]
Right Ramus	1.36±0.15	1.38	(1.04-1.59)	1.36±0.16	1.42	(1.03-1.56)	1.34±0.15	1.35	(1.02-1.56)	0,670[a]
Left Condyle	1.41±0.11	1.42	(1.12-1.59)	1.44±0.08	1.47	(1.24-1.57)	1.44±0.08	1.45	(1.22-1.59)	0,645[a]
Left Gonial	1.32±0.12	1.34	(1.00-1.56)	1.37±0.13	1.40	(1.09-1.59)	1.35±0.13	1.37	(1.03-1.55)	0,181[a]
Left Ramus	1.36±0.12	1.37	(1.05-1.56)	1.37±0.11	1.39	(1.13-1.56)	1.36±0.11	1.37	(1.05-1.56)	0,938[b]
Total Condyle	1.42±0.10	1.43	(1.12-1.59)	1.44±0.08	1.46	(1.22-1.57)	1.43±0.10	1.45	(1.11-1.79)	0,429[a]
Total Gonial	1.34±0.11	1.35	(1.00-1.56)	1.37±0.11	1.39	(1.09-1.59)	1.35±0.12	1.34	(1.03-1.69)	0,291[a]
Total Ramus	1.36±0.14	1.37	(1.04-1.59)	1.36±0.14	1.40	(1.03-1.56)	1.35±0.14	1.37	(1.02-1.56)	0,807[a]

FD: Fractal dimension; SD: Standard deviation; Min: Minimum, Max: Maximum; a Kruskal-Wallis test; b One-way ANOVA

Table 3: *Correlation between FD values and age of patients.*

ROI	Bilateral carious				Non-carious			
	Mean FD±SD	Med (Min-Max)	r	p-value	Mean FD±SD	Med (Min-Max)	r	p-value
Right Condyle	1.43±0.09	1.45 (1.14-1.58)	-0.42	0.007*	145±0.07	1.46 (122-1.56)	0.04	0.786
Right Gonial	1.36±0.10	1.36 (1.03-1.54)	-0.24	0.132	1.37±0.10	1.37 (1.14-1.54)	0.22	0.168
Right Ramus	1.36±0.15	1.38 (1.04-1.59)	-0.37	0.017*	1.36±0.16	1.42 (1.03-1.56)	0.04	0.787
Left Condyle	1.41±0.11	1.42 (1.12-1.59)	-0.27	0.092	1.44±0.08	1.47 (1.24-1.57)	-0.11	0.475
Left Gonial	1.32±0.12	1.34 (1.00-1.56)	-0.10	0.504	1.37±0.13	1.40 (1.09-1.59)	-0.02	0.865
Left Ramus	1.36±0.12	1.37 (1.05-1.56)	-0.45	0.004*	1.37±0.11	1.39 (1.13-1.56)	0.18	0.268

FD: Fractal dimension; SD: Standard deviation; Min: Minimum, Max: Maximum; r: Spearman's correlation coefficient; * p<0.05; statistically significant

Table 4: *Relationship between FD values of the study groups according to the presence of dentin caries.*

	ROI	C-F		C-M		p	NC-F		NC-M		p	Total C		Total NC		p
		Mean±SD	Med	Mean±SD	Med		Mean±SD	Med	Mean±SD	Med		Mean±SD	Median	Mean±SD	Med	
Unilateral carious	Condyle	1.43±0.12	1.42	1.43±0.10	1.48	0.698[a]	1.42±0.09	1.42	1.45±0.08	1.46	0.412[b]	1.43±0.11	1.46	1.44±0.08	1.45	0.525[c]
	Gonial	1.33±0.11	1.32	1.36±0.12	1.35	0.327[a]	1.36±0.13	1.35	1.35±0.14	1.39	0.887[b]	1.34±0.11	1.33	1.35±0.13	1.37	0.914[c]
	Ramus	1.34±0.14	1.35	1.33±0.17	1.35	0.847[b]	1.35±0.11	1.36	1.38±0.12	1.42	0.265[a]	1.34±0.15	1.35	1.36±0.11	1.37	0.490[c]
		R-F		R-M			L-F		L-M			Total R		Total L		
Bilateral carious	Condyle	1.42±0.11	1.43	1.44±0.08	1.46	0.504[b]	1.42±0.11	1.43	1.41±0.11	1.41	0.849[b]	1.43±0.09	1.45	1.41±0.11	1.42	0.519[d]
	Gonial	1.36±0.10	1.37	1.36±0.10	1.35	0.974[b]	1.34±0.13	1.36	1.30±0.11	1.34	0.339[b]	1.36±0.10	1.36	1.32±0.12	1.34	0.066[d]
	Ramus	1.36±0.15	1.38	1.35±0.15	1.38	0.716[b]	1.37±0.13	1.38	1.34±0.12	1.36	0.476[b]	1.36±0.15	1.38	1.36±0.12	1.37	0.973[c]
Non-carious	Condyle	1.46±0.08	1.47	1.44±0.06	1.44	0.201[a]	1.43±0.07	1.46	1.44±0.10	1.47	0.717[b]	1.45±0.07	1.46	1.44±0.09	1.47	0.468[c]
	Gonial	1.38±0.07	1.40	1.35±0.12	1.35	0.311[b]	1.34±0.11	1.38	1.39±0.13	1.41	0.231[a]	1.37±0.10	1.37	1.37±0.13	1.40	0.952[d]
	Ramus	1.35±0.16	1.41	1.38±0.16	1.47	0.414[a]	1.37±0.11	1.36	1.37±0.11	1.40	0.936[b]	1.36±0.16	1.42	1.37±0.11	1.39	0.898[c]

Right: R; Left: L; Carious: C; Non-carious: NC; Female: F; Male: MSD: Standard deviation; FD: Fractal dimension; a Mann-Whitney U test; b Independent samples t-test; c Wilcoxon signed sequence test; d Paired samples t-test

cal processes. When the examined body structure becomes complex, the FD value increases and decreases when it becomes simpler (18). FD analysis is a non-invasive method, obtained through quantitative analysis of processed images. Standardization of the obtained images is of great importance for the accuracy of the method (19). In recent years, FD analysis has been used in many studies investigating bone structures (12,18-20). In this study, standardized digital panoramic radiography images were used. Trabecular bone is more determinant in evaluating changes in bone structure because it has a higher metabolic activity compared with cortical bone (21). For this reason, we were cautious to include no tissue other than trabecular bone in the ROIs determined in our study. Also, because age-related factors have a great effect on the structure of trabecular bone, the age range was kept narrow (18). Yasar and Akgünlü (7) used FD analysis to investigate differences in the trabecular structure of toothed areas and edentulous regions. According to their results, the low FD values of the toothed areas correlated with the fact that these regions had a more organized trabecular structure to resist the mechanical force transmitted to the jawbone via the teeth (7). By contrast, in a study in which Wilding *et al*. (22) evaluated toothed areas and edentulous regions using FD analysis, the authors emphasized that the FD values of the toothed regions were higher than the toothless regions. However, traditional radiographs and dried mandibles were used in this study. In patients with unilateral caries, it can be expected that the trabecular structure would change due to the decrease in the chewing efficiency and the force transmitted to the jawbone due to the decrease in the inter-arch occlusal contact area on the carious side, a change in the trabecular structure, and lower FD values in the non-carious area compared with the carious area. Statistically, no significant difference was found between the FD values of the ROIs determined on the right and left in this patient group in our study. The reason for this situation could be that the changes in chewing performance as a result of caries were not intense enough to change bone trabeculation.

Gülec *et al*. (18) evaluated the trabecular bone formation in the jawbone in patients with and without bruxism using FD analysis performed on digital panoramic radiographs. According to their results, the FD values of bruxers were lower than in the non-bruxer group. This was attributed to the resorptive changes that occurred due to the excessive forces transmitted to the jawbone. The authors also reported that the reason for achieving a statistically significant result only on the right side in the bruxer group might be the unilateral chewing pattern that developed due to the larger amount of caries and/or restorations on the left sides of the patients. In our study, no statistically significant difference was found when the FD values of the determined ROIs of the individuals with and without caries on both sides were compared. However, bruxism is a condition characterized by excessive activity of masticatory muscles, so the force transmitted to the jawbone is greater (23). Although the maximum force and application time applied in patients with bruxism are higher, the applied force and application time is lower with normal chewing, and the maximum bite force is generally not used during usual chewing (24,25). The force applied to the posterior during chewing is 2-12 kg (20-120 N) depending on the type of food in healthy individuals, whereas this

value can reach up to 22-26 kg (220-260 N) in bruxism (25). It is also known that children aged 8-11 years have lesser chewing performance (26). The force transmitted to the jawbone during normal chewing in children may not cause any changes in trabeculation. However, because the chewing efficiency increases with age, the relation of average FD values of group 3 with age was found statistically significant in our study. A negative correlation was found between age and mean FD values in the right condyle, right ramus, and left ramus regions. No statistically significant relationship was found between sex and mean FD values.

The lack of clinical examinations is a limitation of this study. More studies are needed to evaluate the effects of chewing on growth and development using objective parameters. Another limitation of this study is that the post hoc power analysis results were 16%, the results should be evaluated carefully because the sample size is insufficient. The reason for the low number of patients obtained in the retrospective screening was the classification of patients aged 8-13 years only according to the level of caries in the permanent first molars. The inclusion criteria depended on many parameters, such as the expectation that there will be no caries in other teeth and the patient's systemic health. For this reason, it can be suggested to enrich the study by increasing the sample size in new studies.

Conclusion

According to the results of our study, there is no relationship between tooth decay and trabeculation of the jawbone in children aged 8 to 13 years.

Türkçe Özet: *Çocuk Hastalarda Diş Çürüğü ile Trabeküler Kemik Yapısı Arasındaki İlişkinin Fraktal Analiz Yöntemi ile Değerlendirilmesi: Retrospektif Çalışma. Amaç: Çiğneme hareketi, stomatognatik sistemin büyümesi ve gelişmesi üzerinde etkilere sahiptir. Çiğneme üzerine etkisi olduğu bilinen diş çürüğü, çene kemiğine iletilen mekanik kuvvetler üzerindeki dolaylı etkisinden dolayı çene kemiğini etkileyebilir. Bu çalışmada çocuklarda büyüme ve gelişme süreçlerinde diş çürüğü ile çene kemiği trabekülasyonu arasındaki ilişkinin fraktal boyut (FB) analizi yöntemi ile değerlendirilmesi amaçlanmıştır. Gereç ve Yöntem: Çalışmaya katılan toplam 120 hasta üç gruba ayrıldı. Gruplar; Grup 1: Derin dentin çürüğü / apikal rarefiye osteiti olmayan 40 hasta, Grup 2: Sağ veya sol tarafta derin dentin çürüğü / apikal rarefiye osteiti olan 40 hasta ve Grup 3: sağ ve sol tarafta derin dentin çürüklü hasta / apikal rarefiye osteit, bulunan 40 hasta olacak şekilde belirlendi. Seçilen hastaların dijital panoramik görüntüleri FB analizi ile değerlendirildi. Bulgular: Gruplar arasındaki FB analizi istatistiksel olarak anlamlı değildi (p> 0.05). Grup içi değerlendirmede yaş ve cinsiyet faktörleri istatistiksel olarak anlamlı bulunmadı (p> 0.05). Grup 3'te sağ kondil (r = -0.42; p <0.05), sağ ramus (r = -0.37; p <0.05) ve sol ramus (r = -0.45; p <0.05) FB değerleri ile yaş arasında negatif korelasyon bulundu. Sonuç: 8-13 yaş arası çocuklarda diş çürüğü ile çene kemiğinin trabekülasyonu arasında bir ilişki yoktur. Anhtar Kelimeler: Diş çürükleri, fraktal, kemik, mandibula; radyoloji.*

Ethics Committee Approval: This study was reviewed and approved by the Recep Tayyip Erdoğan University Clinical Studies Ethics Committee (2020/127).

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: DNG participated in designing the study. DNG participated in generating the data for the study. SME participated in gathering the data for the study. SA participated in the analysis of the data. SA wrote the majority of the original draft of the paper. DNG, TEK participated in writing the paper. DNG has had access to all of the raw data of the study. SME has reviewed the pertinent raw data on which the results and conclusions of this study are based. SME have approved the final version of this paper. DNG, SME guarantee that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they have received no financial support.

References

1. Manohar N, Hayen A, Fahey P, Arora A. Obesity and dental caries in early childhood: A systematic review and meta-analyses. Obes Rev 2020; 21: e12960. [CrossRef]
2. Kaya MS, Akyuz S, Guclu B, Diracoglu D, Yarat A. Masticatory parameters of children with and without clinically diagnosed caries in permanent dentition. Eur J Paediatr Dent 2017; 18: 116-20.
3. Gavião MBD, Raymundo VG, Rentes AM. Masticatory performance and bite force in children with primary dentition. Braz Oral Res 2007; 21: 146-52. [CrossRef]
4. Haralur SB, Majeed MI, Chaturvedi S, Alqahtani NM, Alfarsi M. Association between preferred chewing side and dynamic occlusal parameters. J Int Med Res 2019; 47: 1908-15. [CrossRef]
5. Decerle N, Nicolas E, Hennequin M. Chewing deficiencies in adults with multiple untreated carious lesions. Caries Res 2013; 47: 330-7. [CrossRef]
6. de Souza Barbosa T, de Morais Tureli MC, Nobre-dos-Santos M, Puppin-Rontani RM, Gavião MBD. The relationship between oral conditions, masticatory performance and oral health-related quality of life in children. Arch Oral Biol 2013; 58: 1070-7. [CrossRef]
7. Yasar F, Akgünlü F. Fractal dimension and lacunarity analysis of dental radiographs. Dentomaxillofac Rad 2005; 34: 261-7. [CrossRef]
8. Jolley L, Majumdar S, Kapila S. Technical factors in fractal analysis of periapical radiographs. Dentomaxillofac Rad 2006; 35: 393-7. [CrossRef]
9. Updike SX, Nowzari H. Fractal analysis of dental radiographs to detect periodontitis-induced trabecular changes. J Periodontal Res 2008; 43: 658-64. [CrossRef]
10. Ergün S, Saracoglu A, Güneri P, Özpınar B. Application of fractal analysis in hyperparathyroidism. Dentomaxillofac Rad 2009; 38: 281-9. [CrossRef]
11. Heo MS, Park KS, Lee SS, Choi SC, Koak, JY, Heo SJ, Kim JD. Fractal analysis of mandibular bony healing after orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002; 94: 763-7. [CrossRef]
12. Göller Bulut D, Bayrak S, Uyeturk U, Ankarali H. Mandibular indexes and fractal properties on the panoramic radiographs of the patients using aromatase inhibitors. Brit J radiol 2018; 91: 20180442. [CrossRef]
13. Linas N, Peyron MA, Eschevins C, Hennequin M, Nicolas E, Collado V. Natural food mastication capability in preschool children according to their oral condition: a preliminary study. J Texture Stud 2020; 51: 755-65. [CrossRef]
14. Lemos AD, Gambareli FR, Serra MD, de Liz Pocztaruk R, Gavião MBD. Chewing performance and bite force in children. Braz J Oral Sci 2006; 5: 1101-8.
15. Van Der Bilt A, Tekamp A, Van Der Glas H, Abbink J. Bite force and electromyograpy during maximum unilateral and bilateral clenching. Eur J Oral Sci 2008; 116: 217-22. [CrossRef]
16. Tureli MCDM, Barbosa TDS, Gavião MBD; Associations of masticatory performance with body and dental variables in children. Pediatr Dent 2010; 32: 283-8.

17. Su CM, Yang YH, Hsieh TY. Relationship between oral status and maximum bite force in preschool children. J Dent Sci 2009; 4: 32-9. [CrossRef]
18. Gulec M, Tassoker M, Ozcan S, Orhan K. Evaluation of the mandibular trabecular bone in patients with bruxism using fractal analysis. Oral Radiol 2020; 1-10. [CrossRef]
19. Kato CN, Barra SG, Tavares NP, Amaral TM, Brasileiro CB, Mesquita RA, Abreu LG. Use of fractal analysis in dental images: a systematic review. Dentomaxillofac Radiol 2020; 49: 20180457. [CrossRef]
20. Baksi BG, Fidler A. Fractal analysis of periapical bone from lossy compressed radiographs: a comparison of two lossy compression methods. J Digit Imaging 2011; 24: 993-8. [CrossRef]
21. Jolley L, Majumdar S, Kapila S. Technical factors in fractal analysis of periapical radiographs. Dentomaxillofac Radiol 2006; 35: 393-7. [CrossRef]
22. Wilding RJC, Slabbert JCG, Kathree H, Owen CP, Crombie K, Delport P. The use of fractal analysis to reveal remodelling in human alveolar bone following the placement of dental implants. Arch Oral Biol 1995; 40: 61-72. [CrossRef]
23. Jadhao VA, Lokhande N, Habbu SG, Sewane S, Dongare S, Goyal N. Efficacy of botulinum toxin in treating myofascial pain and occlusal force characteristics of masticatory muscles in bruxism. Indian J Dent Res 2017; 28: 493. [CrossRef]
24. Pedroni-Pereira A, Marquezin MCS, Araujo DS, Pereira LJ, Bommarito S, Castelo PM. Lack of agreement between objective and subjective measures in the evaluation of masticatory function: A preliminary study. Physiol Behav 2018; 184: 220-5. [CrossRef]
25. Cosme DJ, Baldisserotto SM, Canabarro SA, Shinkai RS. Bruxism and Voluntary Maximal Bite Force in Young Dentate Adults. Int J Prosthodont 2005; 18: 328–32.
26. Mc Donnell ST, Hector MP, Hannigan A. Chewing side preferences in children. J Oral Rehabil 2004; 31: 855-60. [CrossRef]

eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2022; 56(2): 74-79

Original research

Skeletal and dentoalveolar dimensions in unilateral impacted canınes: a cone beam computed tomography study

Sanjit Kumar Sar[1], **Mandeep Singh**[1], **Ankit Sharma**[1], **Payal Sharma**[1], **Monis Raza**[1]

Purpose

To compare skeletal and dentoalveolar measurements of subjects with unilateral impacted canine versus the non-impacted contralateral side using cone beam computed tomography (CBCT).

Materials and Methods

30 CBCTs with unilaterally impacted maxillary canines (Buccal=15, Palatal=15) were selected. Skeletal and dentoalveolar variables (alveolar ridge height of incisors, dentoalveolar height, angulations of incisors and canines, basal lateral width and premolar width) were compared between the impacted and the contralateral sides. Independent t-test was used to compare the variables.

Results

There was a significant difference in the mean basal lateral width between the impacted (28.25±1.83 mm) and non-impacted (31.64±2.18 mm) sides. Premolar width was significantly lower on the impacted side ($p<0.05$). The canines exhibited significantly greater angulations on the impacted side compared to the non-impacted side. The basal lateral width was significantly higher in the buccal subgroup (29.03±1.65mm) compared to palatal (27.48±1.70mm) on the impacted side. The intra-operator reliability was found to be high (0.99%).

Conclusion

Significant differences were seen in canine angulation, premolar width and basal lateral width between impacted vs. non impacted sides. Basal lateral width was higher in buccal impacted cases compared to palatal.

Keywords: *Impacted canine, CBCT, skeletal dimensions, diagnosis, orthodontic treatment*

Introduction

An impacted tooth is one that is stopped from erupting into place due to malposition, lack of space, or other obstructions, according to Mead in early 1954. Later, Peterson defined impacted teeth as teeth that do not erupt into the dental arch in the expected period. Farman defined impacted teeth as teeth that are stopped from erupting due to a physical impediment in the eruption route (1, 2). Maxillary canines, after third molars, are the second most common teeth that are impacted, with prevalence varying from 1.80% to 3.29%, depending on the demographic studied (3). According to D'Oleo-Aracena *et al.* (4), incidence of impacted canine is more prevalent in females with a ratio of 2:1, and the frequency in the maxilla is more than double that of the mandible.

The maxillary canine has the longest eruption route of all the teeth, beginning right below the orbit's floor. It then takes a circuitous route into the oral cavity, guided by lateral incisor`s root. The causative factors of impacted maxillary canines include maxillary lateral incisor`s aberrant

ORCID IDs of the authors: S.K.S. 0000-0001-7272-9675; M.S. 0000-0003-4562-9593; A.S. 0000-0002-7521-7293; P.S. 0000-0002-0062-3940; M.R. 0000-0003-3705-3678

[1]Department of Orthodontics and Dentofacial Orthopaedics, I.T.S Centre for Dental Studies and Research, Muradnagar, Ghaziabad, Uttar Pradesh, India

Corresponding Author: Monis Raza

E-mail: monis8raza@gmail.com

Received: 8 April 2021
Revised: 10 August 2021
Accepted: 21 September 2021

DOI: 10.26650/eor.2022911925

How to cite: *Sar SK, Singh M, Sharma A, Sharma P, Raza M. Skeletal and dentoalveolar dimensions in unilateral impacted canınes: a cone beam computed tomography study. Eur Oral Res 2022; 56(2): 74-79. DOI: 10.26650/eor.2022911925*

morphology, disturbance in the dental lamina of developing canines, premature development of the canine, and microform of the cleft lip and palate (5).

Palatally impacted canines are two or three times more common than buccally impacted canines (6). Palatal impactions of canines are frequently associated with the presence of enough space in the dental arch, whereas most labial impactions of canines are associated with crowding. Dental arch space insufficiency was seen in 83% of arches with labial displacement of maxillary canines, according to Jacoby (7). Guidance hypothesis and genetic theory are the two main explanations for the development of an impacted palatal canine. From a regulatory point of view, local conditions such as the primary canine retention and / or absence, malformations, or abnormalities of the maxillary lateral incisor contribute to canine eruption (5). Genetic theory, on the other hand, states that the conflict is caused by genetic predisposition, and is supported by evidence showing a link between affected canines and other phenotypic dental variants of genetic origin, such as the small size of the lateral incisor crown, lateral incisor agenesis, aplasia of premolars and third molars, distal dislocation of mandibular second premolars (8).

The impaction might cause changes in the alveolar bone's dimensions or disrupt the dental angulations of surrounding teeth. Subjects with maxillary canine impactions showed a transverse maxillary deficit in the anterior section of the dental arch, according to McConnell *et al*. (9).

The effect of canine impaction on alveolar maxillary dimensions has been evaluated in several studies (4,8,10). Compared with the unaffected side, Tadinada *et al*. (10) found that buccal-palatal width, height of floor of nasal cavity to alveolar ridge, and dental arch perimeter were significantly reduced towards the affected side. Lateral incisor roots near the affected palatal canines are more angulated than those of the lateral incisors near canines that erupt normally, according to Kanavakis *et al.* (8). On the affected side, D'Oleo-Aracena *et al.* (4) found reduced arch width in the area of the primary premolars and increased distal angulation of lateral incisors.

Cone beam computed tomography (CBCT) imaging is a precise and reliable method of detecting the exact position of an impacted tooth as well as measuring alveolar bone dimensions. In cases of palatally impacted canines of one side alone, previous investigations examined alveolar bone widths and heights on the impacted and non-impacted sides (4, 10). However, none of the investigations have taken into account canines that have been impacted buccally.

Therefore, this study aims to compare the skeletal and dento-alveolar dimensions in subjects with maxillary unilateral impacted canines, buccal or palatal versus the unaffected contralateral side using CBCT. The null hypothesis of the study was there is no difference in skeletal and dento-alveolar dimensions between impacted vs. nonimpacted side and buccal vs. palatal sides.

Materials and methods

Study design and sample size estimation

This cross-sectional and retrospective study with a split mouth design was a multi-centre study. The sample consisted of CBCT's of subjects with unilateral maxillary impacted canines sourced from the archives of dental diagnostic centres specialising in CBCT imaging. Sample size calculation considered a mean difference of 2 mm in premolar width as clinically significant. A level of significance of 0.05 and 80% power required a sample of 28 sides with impacted and non-impacted canines each. Therefore, a sample of 30 CBCT's with unilateral canine impaction was taken for the study.

Ethical statement

The institutional ethics committee granted the ethical clearance to this study (IIEC/RP/2019/002).

Study participants

The inclusion criteria for the CBCTs were patient`s age older than 15 years of both sexes, canines fully calcified, unilateral maxillary canine impaction, fully erupted contralateral canine and no history of any previous orthodontic treatment. Points for exclusion included poor image quality, tooth agenesis evident in CBCT scan, pathologies associated with the follicle like enlargement or cystic changes, CBCT scans demonstrating mesial migration of 1st premolar or distal migration of lateral incisor in impacted canine position, or any other pathology, dento-alveolar traumas, maxillary canine transpositions, craniofacial malformations, bilateral impacted maxillary canines, and patients with multiple impacted teeth.

30 CBCT scans that fulfilled the selection criteria were distributed into two separate groups: Group I (Non impacted) and Group II (Impacted) among which 15 had palatally impacted maxillary canine (subgroup A) and 15 had buccal impaction of maxillary canine (subgroup B). Evaluating the CBCT scans in axial section with lateral incisor and first premolar as reference teeth, position of impacted canine was determined, that is, buccal or palatal.

Image acquisiton and analysis

Imaging was performed with 6 mA and 90 Kv settings using a Newtom 3D scanner (Newtom Giano, Cefla s.c., Italy). The image volume of all patients' CBCT scans was acquired using an 11 x 08 cm field of view with 0.15 mm isotropic voxel sizes and a 25-second exposure time. The DICOM pictures were analysed using NNT (New Net Technologies Ltd, Naples, Florida) software, which contained multiplanar reconstructions as well as 3D reconstructions in volume rendering mode and anteroposterior radiographs generated from CBCTs. All measurements were taken by a single calibrated radiologist and given in millimeters (mm) and degrees (°). An experienced Oral and Maxillofacial Radiology specialist performed the calibration. Anteroposterior radiographs produced from CBCTs in MIP coronal views were used to assess the skeletal and dentoalveolar variable heights, as well as the angulations of incisors and canines (Figure 1 A,B,C,D), and the widths of dentoalveolar variables (Figure 2 A,B,C) were measured in axial sections. The mid-sagittal plane was used as a reference plane for measuring alveolar

ridge height, dentoalveolar height, incisor and canine angulations, and basal lateral width, whereas the middle palatine raphe was used as a reference plane for measuring premolar width. The impacted and contralateral sides, as well as buccal and palatal impacted canines, were compared in terms of the assessed characteristics. All of the measurements were redone by the same examiner after a week.

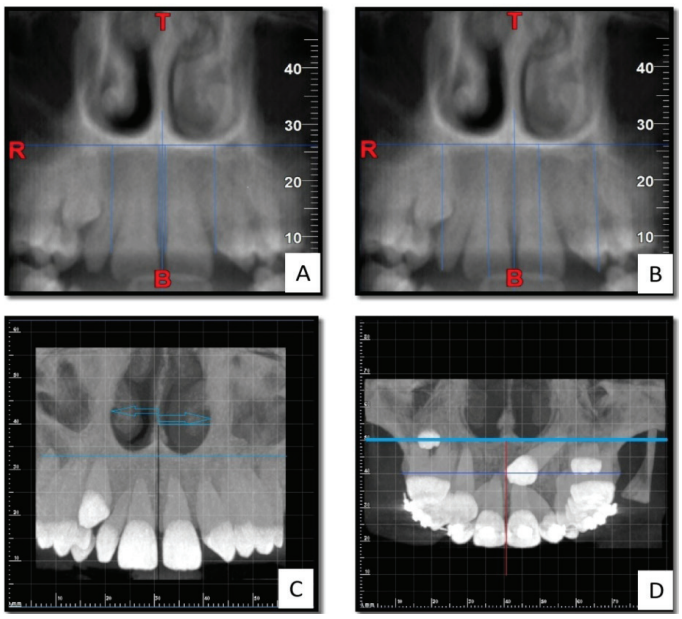


Figure 1. *A- Anterior alveolar ridge height, B- Anterior dentoalveolar height, C- Nasal cavity width and D- Basal lateral width.*

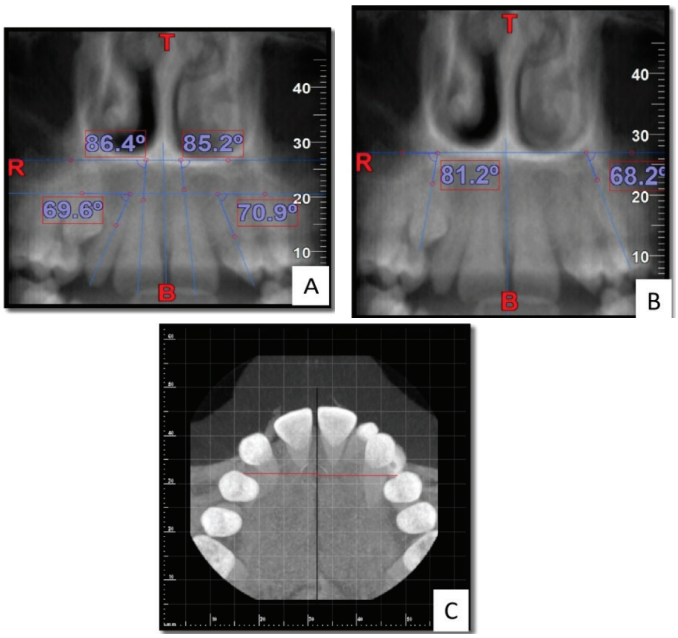


Figure 2. *A- Lateral angulation of long axis of the incisors with respect to the nasal horizontal plane, B- Lateral angulation of long axis of canines with respect to the nasal horizontal plane, C- Premolar width.*

Variables measured on CBCT images and their definitions

1. Anterior alveolar ridge height (AARH-CI and AARH-LI)- distance from the bone ridge of upper central incisors (CI) and lateral incisors (LI) to the floor of the nostrils towards the side of impacted canine and on the side without impaction by drawing a straight line parallel to the mid-sagittal plane.
2. Anterior dentoalveolar height (ADH) is distance from the upper incisor edge to the floor of the nostrils on the side of the impacted canine and the side without impaction by drawing a straight line parallel to the midsagittal plane.
3. Nasal cavity width(NCW)- The distance between the anterior nasal spine and the lateral wall of the nasal base on the side of the impacted canine and the canine without impaction is measured in mm.
4. Basal lateral width (BLW)- The distance between the anterior nasal spine and the outermost dentoalveolar rim on the side of the impacted canine and the side of the canine without impaction is measured in millimetres.
5. Lateral angulation of the incisors' long axis with respect to the nasal horizontal plane (ACI and ALI)- Value of the external angle of the central incisors' (CI) and lateral incisors' (LI) longitudinal axes with respect to the tangent of the nostril floor in both quadrants.
6. Lateral angulation of the long axis of canines with respect to the nasal horizontal plane (AC) - Value of the external angle of the impacted canine's longitudinal axis with regard to the tangent of the nostril floor that has no impaction.
7. Premolar width (PW) - The distance in millimetres between the canine (deciduous or permanent) and first premolar on each side, measured in the axial cut at bone crest level, from the middle palatine raphe to the proximal alveolar bone crest.

Statistical analysis

SPSS version 16.0 (Chicago, IL, USA) was used for the statistical analysis. The study groups were subjected to descriptive statistics. To see if the data was regularly distributed, the Shapiro-Wilk test was used. An independent t-test was used to compare the results. For all tests, statistical significance was determined at a level of $p<0.05$.

Results

13 males (mean age 20.3± 3.0 years) and 17 females (mean age 19.4±3.6 years) were included in the present study. The method of acquiring measures was performed by the second examiner, and the measurements were compared to the first examiner's measurements using the intraclass correlation coefficient for inter-examiner reproducibility (ICC). The ICC values were found to be statistically insignificant, indicating high reliability, with a mean of 0.91 (ICC 0.88-0.94). A strong correlation was found in intra-examiner reliability analysis (ICC 0.99). In terms of the acquired results, the post hoc Power (1-err prob) was 0.8878047, indicating that the sample size was appropriate.

Table 1 shows the comparison of measured variables between the impacted vs the non-impacted sides. The basal lateral width was significantly greater on the non-impacted side compared to the impacted side whereas the angulation of canine was significantly greater on the impacted sides,

in both the buccal and palatal impaction cases. In the palatal impaction cases, a significant difference was also seen in the premolar width (p=0.03) whereas a significant difference was observed in the angulation of the central incisor (p=0.002) in the buccal impaction cases.

Table 2 shows the comparison of the buccal vs the palatal canine impaction subgroups. In the non-impacted side, the angulation of central incisors (p=0.03) was greater in the buccal compared to the palatal cases by 2.45 °. On the impacted side, the basal lateral width in the buccal impaction cases was significantly higher (29.03±1.65 mm) than in the palatal impaction cases (27.47±1.70 mm).

Discussion

CBCT was used to assess skeletal and dentoalveolar variables in the maxillary arch in instances with unilaterally (buccal or palatal) impacted canines to the contra-lateral unaffected site. The accuracy of CBCT in measuring alveolar dimensions has previously been documented (4,8,10). The number of females (n=17) in the sample was higher than the number of males (n=13). This is consistent with prior research that found a higher prevalence of impacted canines in females (4,11,12).

The study found that the side with impacted tooth and the normal sides had substantial differences in basal lateral width, premolar width, and canine angulation. However, there was no significant difference between the impacted and non-impacted groups in anterior alveolar ridge height, anterior dento-alveolar height of incisors, nasal cavity width, or incisor angulation. Because the alveolar process develops in response to tooth eruption, it's plausible to assume that the canine tooth's non-eruption/impaction resulted in changed alveolar dimensions on the impacted side (13,14). In cases of unilateral palatal canine impactions, certain earlier investigations have found a variation in maxillary alveolar dimensions and tooth angulations (4,10,15,16). When compared to the non-impacted side, Tadinada *et al.* (10) found that the impacted side had considerably smaller bucco-palatal width (BP), nasal floor to alveolar crest length, and arch perimeter. The bucco-palatal breadth was reduced at a level of 2mm above the alveolar crest in their study, but not at 6 or 10mm apically. The presence of impacted canine higher in the alveolar crest was the main reason for this. They claimed that bone loss was greater in the horizontal than in the vertical dimension. This is supported by our findings, which show that there were substantial changes in width measurements (basal lateral width and premolar width), but not in dento-alveolar heights. The measurement from the mid-palatal raphe to the first premolar on the afflicted side was substantially lower than the side that was normal, according to D' Oleo-Aracena *et al.* (4). They also suggested that canine impaction would have little effect on alveolar heights in the incisor region since the incisors erupt before the canines. Impaction of the maxillary canine has been linked to

Table 1: *Descriptive statistics and comparison of impacted vs. non impacted sides.*

			Palatal impacted canine			Buccal impacted canine		
Variables	**Groups**	**N**	**Mean ± SD**	**Mean Difference**	***p* Value**	**Mean ± SD**	**Mean Difference**	***p* Value**
AARH-CI	Group I	15	17.11±2.72	0.27	0.78	17.81±2.58	-0.19	0.85
	Group II	15	16.84±2.45			17.99±2.87		
AARH-LI	Group I	15	16.83±2.64	0.11	0.92	18.67±3.67	0.64	0.62
	Group II	15	16.72±3.16			18.03±3.23		
ADH-CI	Group I	15	25.17±3.48	0.49	0.7	26.89±2.59	0.57	0.53
	Group II	15	24.68±3.41			26.32±2.39		
ADH-LI	Group I	15	23.63±4.16	-0.37	0.79	25.54±3.07	0.47	0.68
	Group II	15	23.99±3.21			25.07±3.16		
NCW	Group I	15	12.28±1.007	0.34	0.44	11.81±1.41	-0.33	0.52
	Group II	15	11.94±1.33			12.14±1.34		
BLW	Group I	15	30.89±1.41	3.43	0.00*	32.39±2.57	3.37	0.00*
	Group II	15	27.47±1.7			29.03±1.66		
ACI	Group I	15	87.25±2.74	-0.09	0.96	89.71±3.31	4.19	0.002*
	Group II	15	87.34±5.76			85.51±3.59		
ALI	Group I	15	77.1±7.62	-1.42	0.65	77.14±6.42	0.95	0.78
	Group II	15	78.52±9.22			76.19±11.46		
AC	Group I	15	83.59±9.44	-30.83	0.00*	75.39±13.09	-25.18	0.00*
	Group II	15	114.42±20.86			100.57±20.87		
PW	Group I	15	18.5±2.44	2.03	0.03*	19.48±3.08	1.6	0.14
	Group II	15	16.47±2.43			17.88±2.63		

Independent t-test, Significant, p≤0.05 SD standard deviation, AARH-CI and AARH-LI: Anterior alveolar ridge height of central incisor (CI) and lateral incisor (LI), ADH: Anterior dentoalveolar height, NCW: Nasal cavity width, BLW: Basal lateral width, ACI and ALI: Lateral angulation of long axis of incisors with respect to the nasal horizontal plane, AC: Lateral angulation of long axis of canines with respect to the nasal horizontal plane, PW: Premolar width

Table 2: *Descriptive statistics and comparison of buccal vs. palatal impacted canine groups.*

			Non impacted side			Impacted side		
Variables	**Groups**	**N**	**Mean ± SD**	**Mean Difference**	***p* Value**	**Mean ± SD**	**Mean Difference**	***p* Value**
AARH-CI	Group A	15	17.11±2.72	-0.7	0.48	16.84±2.44	-1.15	0.25
	Group B	15	17.81±2.58			17.99±2.86		
AARH-LI	Group A	15	16.83±2.64	-1.84	0.13	16.72±3.16	-1.31	0.27
	Group B	15	18.67±3.67			18.03±3.23		
ADH-CI	Group A	15	25.17±3.48	-1.72	0.13	24.68±3.40	-1.64	0.14
	Group B	15	26.89±2.59			26.32±2.39		
ADH-LI	Group A	15	23.63±4.16	-1.91	0.16	23.99±3.20	-1.07	0.36
	Group B	15	25.54±3.07			25.07±3.16		
NCW	Group A	15	12.28±1.007	0.46	0.3	11.94±1.32	-0.2	0.68
	Group B	15	11.81±1.41			12.14±1.34		
BLW	Group A	15	30.89±1.41	-1.5	0.06	27.47±1.70	-1.56	0.01*
	Group B	15	32.39±2.57			29.03±1.65		
ACI	Group A	15	87.25±2.74	-2.45	0.03*	87.34±5.76	1.82	0.31
	Group B	15	89.71±3.31			85.51±3.58		
ALI	Group A	15	77.1±7.62	-0.04	0.99	78.52±9.22	2.32	0.54
	Group B	15	77.14±6.42			76.19±11.45		
AC	Group A	15	83.59±9.44	8.20	0.06	114.42±20.86	13.85	0.08
	Group B	15	75.39±13.09			100.57±20.87		
PW	Group A	15	18.5±2.44	-0.98	0.34	16.47±2.42	-1.40	0.14
	Group B	15	19.48±3.08			17.88±2.62		

Independent t-test, Significant, $p \leq 0.05$ *SD* standard deviation, AARH-CI and AARH-LI: Anterior alveolar ridge height of central incisor (CI) and lateral incisor (LI), ADH: Anterior dentoalveolar height, NCW: Nasal cavity width, BLW: Basal lateral width, ACI and ALI: Lateral angulation of long axis of incisors with respect to the nasal horizontal plane, AC: Lateral angulation of long axis of canines with respect to the nasal horizontal plane, PW: Premolar width

a lack of transverse growth in the front section of the dental arch in studies by McConnell *et al*.(9) and Schindel and Duffy (17). The findings of these investigations suggest that when a transverse maxillary deficit is noted clinically, the possibility of maxillary canine impaction should be considered. At this point, expanding the arch could be termed an interceptive technique. The clinical importance of our findings in terms of treatment suggests that more attention should be paid to correcting asymmetries in transverse dimension, particularly at the level of the first premolar on the side with an impacted canine. Only dental alignment should be used to correct the severity of this asymmetry (about 2 mm between both sides); however, in cases of more severe asymmetry, such as unilateral cross bite, asymmetric expansion could be considered.

The angulations of the impacted canine were substantially bigger than those of the non-impacted canine, and the impacted canine displayed mesial tilting. Hanke *et al*. (3) and D'Oleo-Aracena *et al*. (4) observed similar findings in their previous studies. The average difference in canine angulation between the impacted and non-impacted sides ranged from 25 to 30 degrees. The angulation of the canine is very important in deciding its prognosis. The incisor angulations on the affected and non-impacted sides, however, were not significantly different. D'Oleo-Aracena *et al*. (4) showed a substantial difference in incisor angulation between the affected and non-impacted sides, with greater distal crown angulation on the impacted sides, whereas Kanavakis *et al*. (8) found a 2.5 degree mesial angulation of lateral incisors close to impacted canines.

However, according to D'Oleo-Aracena *et al*. (4), orthodontic treatment in unilateral impacted canines necessitates prior traction; aligning the incisors without distancing the impacted canine could expose the incisor roots to the impacted canine due to their distal angulation with respect to the opposite side without impaction. In addition, orthodontists should place a greater emphasis on rectifying transverse asymmetries, particularly at the level of the breadth between the median raphe and the first premolar on the affected side with an impacted canine.

We discovered no significant variations in the other characteristics between the buccal and palatal impacted canines, except for the basal lateral width, which was substantially greater in the buccal subgroup (29.03±1.65mm) compared to the palatal subgroup (27.48±1.70mm) on the impacted side. The distance between the mid palatine raphe and the proximal alveolar bone crest between the canine and first premolar on the impacted side was significantly shorter than the non-impacted side ($p<0.05$) in palatal impacted canine cases. On the other hand, there was no significant change in premolar width on the impacted side of buccally impacted canines.

The drawbacks of study include a small sample size. Moreover the study did not differentiate the impacted canines according to the severity of impaction. The extent of

displacement of the canines from their normal positions in the arch may have affected the variables studied. The study excluded cases of canine impaction with presence of other dental anomalies such as peg-shaped or diminutive lateral incisors, agenesis of teeth and other anomalies to minimize confounding factors but in actuality, the impaction of canines, especially palatal ones has shown to be associated with such anomalies. Another drawback of this study is the small number of observers.

Conclusion

Within limitations, the following conclusions may be drawn from the study: Significant differences were observed in the canine angulation, premolar width and basal lateral width between the impacted vs. contra-lateral sides. Basal lateral width and premolar width were more on the non- impacted sides than impacted sides. Canine angulation on the side with impaction was substantially higher than on the contra-lateral side. On the buccal impacted sides, the basal lateral width was much bigger than on the palatal impacted sides.

Türkçe Özet: *Tek taraflı gömülü köpek dişleri olan olgularda iskeletsel ve dentoalveolar boyutların konik ışınlı bilgisayarlı tomografi kullanılarak karşılaştırılması. Amaç: Konik ışınlı bilgisayarlı tomografi (KIBT) kullanarak tek taraflı gömülü köpek dişleri olan hastalarda dişin olduğu taraf ile olmayan tarafın iskeletsel ve dentoalveolar ölçümlerini karşılaştırmak amaçlanmıştır. Gereç ve Yöntem: Tek taraflı gömük maksiller kaninlere (Bukkal=15, Palatal=15) sahip 30 KIBT görüntüsü seçilmiştir. İskeletsel ve dentoalveolar değişkenler (kesici dişlerin alveolar kret yüksekliği, dentoalveolar yüksekliği, kesici dişlerin ve köpek dişlerinin açıları, bazal lateral genişlik ve premolar genişlik) gömülü dişin olduğu taraf ve olmayan karşı taraf arasında karşılaştırıldı. Değişkenleri karşılaştırmak için bağımsız t testi kullanıldı. Bulgular: Gömülü (28.25±1.83 mm) ve etkilenmemiş (31.64±2.18 mm) taraflar arasında ortalama bazal lateral genişlik açısından anlamlı bir fark vardı. Gömülü tarafta premolar genişliği anlamlı olarak daha düşüktü (p<0.05). Köpek dişleri, etkilenmemiş tarafa kıyasla, etkilenen tarafta önemli ölçüde daha büyük açılar sergiledi. Bukkal alt grupta (29.03±1.65mm) gömük tarafta palatal (27.48±1.70mm) ile karşılaştırıldığında bazal lateral genişlik anlamlı olarak daha yüksekti. Ölçümcü içi güvenilirlik yüksek (%0.99) bulundu. Sonuç: Gömülü ve gömülü olmayan taraflar arasında köpek dişinin açılanması, premolar genişlik ve bazal lateral genişlikte önemli farklılıklar görüldü. Bukkal pozisyonda gömülü diş olan olgularda bazal lateral genişlik palatal ile karşılaştırıldığında daha yüksekti.*

Ethics Committee Approval: Ethical clearance was obtained from the institutional ethics committee (IIEC/RP/2019/002).

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: SKS, MS, PS participated in designing the study. SKS, MS, AS, PS, MR participated in generating the data for the study. SKS, MS, AS participated in gathering the data for the study. SKS, MS, AS participated in the analysis of the data. SKS wrote the majority of the original draft of the paper. SKS, MS, AS, PS, MR participated in writing the paper. SKS, MS, AS, PS, MR have had access to all of the raw data of the study. SKS, MS, PS have reviewed the pertinent raw data on which the results and conclusions of this study are based. SKS, MS, AS, PS, MR have approved the final version of this paper. MR guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they did not receive any financial support.

References

1. Juodzbalys G, Daugela P. Mandibular third molar impaction: review of literature and a proposal of a classification. J Oral Maxillofac Res 2013;4:e1. [CrossRef]
2. Abdel-Salam E, El-Badrawy A, Tawfik AM. Multi-detector dental CT in evaluation of impacted maxillary canine. Egypt J Radio Nucl Med 2012;43:527-34. [CrossRef]
3. Hanke S, Hirschfelder U, Keller T, Hofmann E. 3D CT based rating of unilateral impacted canines. J Craniomaxillofac Surg 2012;40:e268-76. [CrossRef]
4. D Oleo-Aracena MF, Arriola-Guillén LE, Rodríguez-Cárdenas YA, Ruíz-Mora GA. Skeletal and dentoalveolar bilateral dimensions in unilateral palatally impacted canine using cone beam computed tomography. Prog Orthod 2017;18:1-7. [CrossRef]
5. Jena AK, Duggal R. The pattern of maxillary canine impaction in relation to anomalous lateral incisors. J ClinPediatr Dent 2010;35:37-40. [CrossRef]
6. Walker L, Enciso R, Mah J. Three-dimensional localization of maxillary canines with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2005;128:418-23. [CrossRef]
7. Jacoby H. The etiology of maxillary canine impactions. Am J Orthod Dentofacial Orthop 1983;84:125-32. [CrossRef]
8. Kanavakis G, Curran KM, Wiseman KC, et al. Evaluation of crown-root angulation of lateral incisors adjacent to palatally impacted canines. Prog Orthod 2015;16:1-6. [CrossRef]
9. McConnell TL, Hoffman DL, Forbes DP, Janzen EK, Weintraub NH. Maxillary canine impaction in patients with transverse maxillary deficiency. ASDC J Dent Child 1996;63:190-5.
10. Tadinada A, Mahdian M, Vishwanath M, Allareddy V, Upadhyay M, Yadav S. Evaluation of alveolar bone dimensions in unilateral palatally impacted canine: a cone-beam computed tomographic analyses. Eur J Orthod 2015;37:596-602. [CrossRef]
11. Bishara SE. Impacted maxillary canines: A review. Am J Orthod Dentofacial Orthop 1992;101:159-71. [CrossRef]
12. Sajnani AK, King NM. Prevalence and characteristics of impacted maxillary canines in Southern Chinese children and adolescents. J Investig Clin Dent 2014;5:38-44. [CrossRef]
13. Kjaer I. Mechanism of human tooth eruption: review article including a new theory for future studies on the eruption process. Scientifica (Cairo) 2014;2014:1-13. [CrossRef]
14. Wise GE. Cellular and molecular basis of tooth eruption. Orthod Craniofac Res 2009;12:67-73. [CrossRef]
15. Dental and occlusal features in patient with palatally displaced maxillary canines. *Eur J Orthod* 2009;31:367-73. [CrossRef]
16. Dağsuyu IM, Kahraman F, Okşayan R. Three-dimensional evaluation of angular, linear, and resorption features of maxillary impacted canines on cone-beam computed tomography. Oral Radiol 2017;34:66-72. [CrossRef]
17. Schindel RH, Duffy SL. Maxillary transverse discrepancies and potentially impacted maxillary canines in mixed-dentition patients. Angle Orthod 2007;77:430-5. [CrossRef]

eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2022; 56(2): 80-87

Original research

Accuracy of age estimation with Demirjian and Nolla methods in Eastern Turkish children aged 3-17 years old

Gulsum Duruk[1],
Tamara Pelin Gundogdu Ozdal[1],
Sacide Duman[1]

Purpose
Dental age assessment is one of the most reliable methods of chronological age estimation used for criminal, forensic and anthropologic purposes. This study aimed to determine how accurate it was to estimate the chronological age by looking at the dental age measured with the Nolla and Demirjian methods in a Turkish sample, based on the variables of gender and age-group.

Materials and Methods
A retrospective study was performed on panoramic radiographs of 1587 subjects (774 females and 813 males), aged 3–17 years. The mean dental age according to the Demirjian and Nolla methods were compared to the mean chronological age (CA). Also, the percentage value of prediction of CA was determined by using the both methods.

Results
An under-estimation of the chronological age was observed by using Nolla's method (males -0.003, females -0.32, both -0.16) and an over-estimation of the dental age was observed by using Demirjian's method (males 0.61, females 0.75, both 0.68).

Conclusion
Nolla's method was more accurate in the CA estimation than Demirjian's method in Eastern Turkish population.

Keywords: *Nolla method, Demirjian method, dental age, chronological age, Turkish children*

Introduction

Age determination has become an important aspect in current practice. The biological age determination method performed via dental age assessment is one of the methods that are easy to use (1). Dental age assessment helps to make decisions for the treatment procedures both in pediatric dentistry and in orthodontics. Chronological age assessment with the help of dental age also provides great convenience for children who do not have birth certificates, in natural disasters and criminal events (2, 3). Age determination methods used in the field of forensic medicine provide important information about unidentified persons, and also play an important role in the determination of child marriages and child labour (3). In addition, age determination has an important place in the field of medicine and dentistry for the treatment programs designed for the refugee families or children with no identity.

There are many methods related to maturation of permanent teeth and chronological age assessment from dental age. Morrees, Kvaal, Willems, Haavikko, Liliequist, Lundberg, Demirjian, and Nolla are

ORCID IDs of the authors: G.D. 0000-0002-6756-6637; T.P.G.Ö. 0000-0002-3154-5180; S.D. 0000-0001-6884-9674

[1]Department of Pediatric Dentistry, Faculty of Dentistry, Inönü University, Malatya, Turkiye

Corresponding Author: Gulsum Duruk

E-mail: durukgulsum@yahoo.com

Received: 28 February 2021
Revised: 26 September 2021
Accepted: 7 October 2021

DOI: 10.26650/eor.20221057985

How to cite: *Duruk G, Gundogdu Ozdal TP, Duman S. Accuracy of age estimation of Demirjian and Nolla methods in Eastern Turkish children aged 3-17 years old. Eur Oral Res 2022; 56(2): 80-87. DOI: 10.26650/eor.20221057985*

some of them (4-12). Demirjian and Nolla methods are the two most commonly used methods in chronological age estimation. Different results related to dental age can be found in different geographies. The studies conducted in Turkey on the dental age assessment with the Demirjian and Nolla methods are available in the literature (1, 9, 10, 13-15).

Kirzioglu and Ceyhan (9) compared the Nolla and Demirjian methods in 425 Turkish children aged 7-13 years who share the similar socio-economic status and the ethnic group. An underestimation of −0.53 years was found for boys and −0.57 for girls with the Nolla method, this method being more accurate between 9 and 11 years in both genders and in the group of 13-year-old girls. However, the Demirjian method overestimated boys' age by +0.52 and girls' age by +0.75. Kirzioglu and Ceyhan (9) reported that both methods are not totally suitable, with makes it necessary to assess specific tables for this population.

Each population may need their own specific standard for an accurate estimation of chronological age. Since different results are obtained in different countries and regions, there are not many studies that utilize the Demirjian and Nolla methods in Turkey. Therefore, in our study, it was aimed to perform the dental age assessment by using the Demirjian and Nolla methods on the panoramic radiographs taken from children in the Eastern Anatolia Region of Turkey and to bridge the gap due to an insufficient number of studies conducted in our country on this subject. The null hypotheses of this study were as follows: There is no statistically significant difference between the chronological age and dental age. There is no statistically significant difference between the chronological age estimation values according to the Demirjian and Nolla methods.

Materials and Methods

Ethical approval

The present study was approved by the Non-Interventional Clinical Research Ethics Committee of Inönü University, Malatya, Turkey (2020/856).

Sample size estimation

This was a retrospective study conducted on panoramic radiographs. For a confidence level of 90% and $\alpha = 0.05$, at least 271 subjects were needed. The sample consisted of 1587 subjects' panoramic radiographs (774 females and 813 males, ages 3-17.9, (Table 1)).

Study materials

Panoramic radiographs from the subjects who underwent treatment at Inönü University, Faculty of Dentistry, Malatya, Turkey, between January 2016 and December 2017 were included in the study. Eastern Turkish subjects with well-documented chronological ages, aged 3-17.9 years with no prior orthodontic treatment history and good quality of panoramic radiographs were included. Our study did not involve the subjects with systemic diseases affecting the growth and development of the teeth and tooth agenesis other than third molars, vagueness in dental structures due to contrast problems, movements or artifacts, impacted teeth; radiopaque obturations or crowns, periapical lesions, and endodontically treated teeth.

Table 1: *Age distribution of the individuals.*

Age (years)	Female (n)	Male (n)	n	%
3 (3-3.9)	4	4	8	0.5
4 (4-4.9)	17	24	41	2.6
5 (5-5.9)	33	48	81	5.1
6 (6-6.9)	35	49	84	5.3
7 (7-7.9)	71	75	146	9.2
8 (8-8.9)	85	96	181	11.4
9 (9-9.9)	113	117	230	14.5
10 (10-10.9)	105	91	196	12.4
11 (11-11.9)	87	99	186	11.7
12 (12-12.9)	82	84	166	10.5
13 (13-13.9)	72	60	132	8.3
14 (14-14.9)	31	38	69	4.3
15 (15-15.9)	19	14	33	2.1
16 (16-16.9)	12	12	24	1.5
17 (17-17.9)	8	2	10	0.6
Total	774	813	1587	100.0

Observers' characteristics

All assessments were performed by two investigators (GD, TPGÖ) with at least five years of experience in their field in a darkened room with a radiographic illuminator to ensure the contrast enhancement of the images. The assessments were done double-blinded. In order to avoid the examiners bias at the time of collecting data, CA was first recorded on a data collection sheet and the DA scores were tabulated later on a separate sheet.

Chronological age

CA was calculated by subtracting the date of the birth from the date of the panoramic radiograph after having converted both to a decimal age.

Dental age with Demirjian method

The development of the seven left permanent mandibular teeth was rated on an 8-stage scale (from A to H) (Figure 1). Being associated with a stage, each tooth was converted into quantitative values through a specific table. The scores taken from the seven teeth were added up as a gender function, and the sum of dental maturity was obtained on a scale of 0 to 100. The dental maturity score of each subject was then converted to dental age by using standard tables and/or percentile curves which were given for each gender, separately (16).

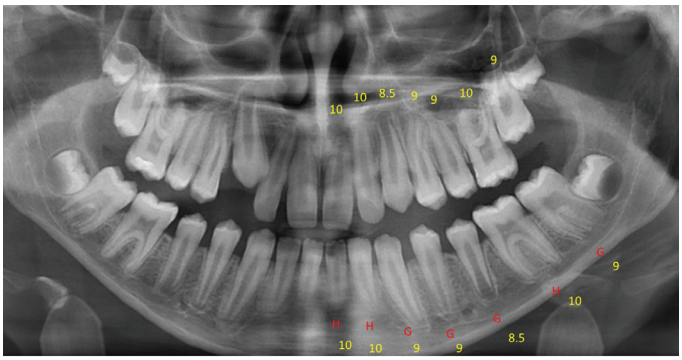


Figure 1. *The scoring of the teeth on a panoramic radiograph according to the Demirjian and Nolla methods.*

Dental age with Nolla method

The development of the seven left permanent mandibular and seven left permanent maxillary teeth was assessed and assigned a stage of between 1 (no sign of calcification) and 10 (apical end completed) (Figure 1). If the tooth was between stages, an appropriate fraction (0.2, 0.5 or 0.7) was added as recommended by Nolla. The calculated-dental age is equivalent to the sum of the Nolla scores. The sum of scores was compared to the average sum for males or females and dental age calculated (17).

The assessment of the inter- and intra-investigators agreements

The Cohen's kappa coefficients on dental age estimation were calculated to the set of seven mandibular teeth staged according to the dental maturity scale of the Demirjian method and seven mandibular and seven maxillary teeth staged according to the dental maturity scale of the Nolla method (Figure 1). To calculate the Cohen's kappa of the inter-rater agreement consistency, a partial examination of the codified data was performed by asking two specialists to codify 60 randomly selected radiographs. To assess the intra-rater agreement reproducibility, the same 60 radiographs were re-examined four weeks after the initial examination by the same two investigators according to both methods.

Statistical analysis

The data was analyzed using IBM SPSS V22 (SPSS Inc., Chicago, IL, USA). The inter- and intra- rater reliability was determined with Cohen's kappa coefficient. Kolmogorov-Smirnov test was performed to check the normality of the data. The dental age and CA were compared using the Paired sample t-test. Pearson correlation coefficient was performed for both methods. Simple regression analysis was used to predict chronological age and to create a regression model. The predictive power of the regression model (R^2) for chronological age was named "the predictive capacity". The significance level was set to $p<0.05$.

Results

The inter- and intra-investigators agreements

The kappa values ranged from 0.94 to 1 (kappa >0.75, good agreement). An average kappa of 0.95 for the Demirjian method and of 0.94 for the Nolla method was recorded as the *inter*-examiner agreement scores. The intra-examiner agreement gave the *kappa values* of 1.00 and 0.98 (for Demirjian and Nolla, respectively) for the examiner 1(GD) and the *kappa values* of 0.98 and 0.97 (for Demirjian and Nolla, respectively) for the examiner 2 (TPGÖ).

Comparison between chronological and estimated age

There was a statistically significant difference between the mean of chronological age and the mean of age estimated according to Demirjian and Nolla methods in females, while there was statistically significant difference between the mean of chronological age and age estimated by only the Demirjian method in males (Table 2). The Nolla method underestimated chronological age, while the Demirjian method overestimated it ($p<0.01$). The overestimation of chronological age by the Demirjian method was statistically significant for both genders ($p<0.001$). On the other hand, the underestimation of chronological age by the Nolla method was statistically significant for females ($p<0.001$) (Table 2).

The mean age differences between the chronological and estimated ages (using the Demirjian and Nolla methods) for gender and age groups are presented in Table 3. The both of methods underestimated chronological age for female, aged <15 years and male, aged <14 years (Table 3). The underestimation was statistically significant for female, while not statistically significant for male (Table 3).

The predictive capacity of the Demirjian and Nolla methods

Analysis of the simple regression had a statical significance when the sum of the seven teeth was considered as a predictor and chronoloical age was considered as a dependent parameter (Table 4). It was determined that the predictive capacity for total variance of chronological age was 77.4% in participants using the Nolla score and was 74.2% in the participants using the Demirjian score.

In our study, the preference of Nolla method over the Demirjian method provided a forecasting gain of 3.2% (R^2 Nolla = 0.774 - R^2 Demirjian = 0.742), for Turkish children aged 3-17 years (Table 4). The Demirjian method predicted 76.3% of total variance of chronological age for male and 71.9% for female, while the Nolla method predicted 80.3% of total variance for male and 74.8% for female. Therefore, when considering the magnitude of the regression coefficients (Table 4), we observed that both methods are able to explain a greater proportion of total variance in male than in female. Comparison of the two methods indicated that the Nolla method had greater predictive capacity than the Demirjian method, for both genders. The forecasting gains using the Nolla method were 2.9% and 4% in female and male, respectively, which indicates very low scores (Table 4). The prediction levels of the Demirjian and Nolla methods on a scale of 0 to 1 by age groups are showed in Figure 2. There was a strong correlation between the chronological age and the estimated age by original Demirjian and Nolla methods (Figure 3).

Table 2: *Comparisons between the chronological and estimated (by Demirjian and Nolla methods) ages in females, males, and overall.*

Age (years)	**Mean**		**SD**	
Chronological	9.69		2.82	
Demirjian estimation	10.36		3.28	
Nolla estimation	9.53		3.23	
Comparisons	**Difference between means**		**SE**	
Demirjian vs. Chronological	0.68***		0.04	
Nolla vs. Chronological	-0.16***		0.04	
Demirjian vs. Nolla	0.833***		0.03	
	Females		**Males**	
Age (years)	**Mean**	**SD**	**Mean**	**SD**
Chronological	9.85	2.81	9.54	2.82
Demirjian estimation	10.59	3.25	10.15	3.30
Nolla estimation	9.53	3.19	9.54	3.27
Comparisons	**Difference between means**	**SE**	**Difference between means**	**SE**
Demirjian vs. Chronological	0.75***	0.06	0.61***	0.06
Nolla vs. Chronological	-0.33***	0.06	0.003	0.05
Demirjian vs. Nolla	1.07***	0.05	0.61***	0.04

SD: Standard Deviation, SE: Standard Error. ***p<0.001.

Table 3: *Difference between means for the chronological and estimated by Demirjian and Nolla methods for ages, for genders and age groups.*

	Female		**Male**	
Age (years)	**DA – CA (SD)**	**NA – CA (SD)**	**DA - CA (SD)**	**NA - CA (SD)**
3	-0.29 (0.19)	0.22 (0.32)	0.24 (0.86)	0.47 (0.67)
4	0.23 (1.53)	0.23 (1.36)	0.56 (1.46)	0.15 (0.58)
5	0.82 (1.09)***	-0.11 (0.58)	0.66 (1.04)***	0.08 (0.65)
6	0.79 (0.67)***	-0.34 (0.76)*	0.66 (0.89)***	-0.26 (0.63)**
7	0.81 (1.44)***	-0.43 (1.12)**	0.73 (1.39)***	0.07 (1.28)
8	0.61(1.53)***	-0.42 (1.17)***	0.31 (0.91)***	-0.15 (0.94)
9	0.58 (1.40)***	-0.45 (0.92)***	0.43 (1.61)**	-0.26 (1.22)*
10	0.82 (1.81)***	-0.31 (1.68)	0.40 (1.77)*	-0.32 (1.44)*
11	0.91 (1.90)***	-0.68 (1.37)***	0.63 (1.66)***	-0.16 (1.57)
12	1.22 (1.77)***	-0.12 (2.18)	1.03 (2.06)***	0.33 (2.11)
13	1.02 (2.12)***	0.18 (2.15)	0.91 (2.20)**	0.59 (2.01)*
14	1.23 (1.22)***	0.66 (1.74)*	1.42 (1.47)***	0.99 (1.43)***
15	0.70 (0.76)***	0.06 (1.58)	-0.34 (2.08)	-0.37 (2.09)
16	-1.78 (2.68)*	-1.97 (2.66)*	-0.21 (0.68)	-0.42 (0.94)
17	-3.07 (2.57)*	-3.67 (2.57)**	-1.92 (0.80)	-2.32 (1.36)
Total	0.75 (1.72)***	-0.32 (1.60)***	0.61 (1.61)***	-0.003 (1.45)

CA: Chronological Age, DA: Demirjian Age, NA: Nolla Age, SD: Standard Deviation, *p<0.05, **p<0.01, ***p<0.001.

Discussion

Recently, there has been an increasing need for fast and inexpensive methods for age determination (18). Chronological age assessment methods with the help of dental maturation follow-up have been performed by many researchers (13, 14, 19-21). However, dental age assessment methods vary according to races and geography. Although there have been studies in different regions of Turkey (Figure 4), their samples were not as large as in our study (1, 9-11, 13-15, 22, 23). In addition, there are only 3 studies comparing Demirjian and Nolla methods within the same study protocol (9, 10, 14). The aim of the present study was to evaluate the usability of Demirjian's (16) and

Table 4: *Simple regression analysis of chronological age estimated by the Demirjian and Nolla methods for total and males-females.*

		Demirjian					Nolla				
		B	SE B	β	t		B	SE B	β	t	
Constant		2.012	0.119		16.886***	Constant	2.363	0.105		22.512***	
Predictor		0.741	0.011	0.86	67.588***	Predictor	0.769	0.010	0.88	73.663***	
Model summary: $R^2 = 0.742$, $p < 0.001$						Model summary: $R^2 = 0.774$, $p < 0.001$					
gender		**B**	**SE B**	**β**	**t**	**gender**		**B**	**SE B**	**B**	**t**
Female	Constant	2.087	0.183		11.429***	Female	Constant	2.592	0.160		16.230
	Predictor	0.733	0.016	0.848	44.444***		Predictor	0.761	0.016	0.865	47.895
	Model summary: $R^2 = .719$, $p < 0.001$						Model summary: $R^2 = 0.748$, $p < 0.001$				
Male	Constant	1.941	0.156		12.425***	Male	Constant	2.147	0.136		15.803
	Predictor	0.749	0.015	0.874	51.120***		Predictor	0.775	0.013	0.896	57.495
	Model summary: $R^2 = 0.763$, $p < 0.001$						Model summary: $R^2 = 0.803$, $p < 0.001$				

CA: Chronological Age, SE: Standard Error, ***$p<0.001$

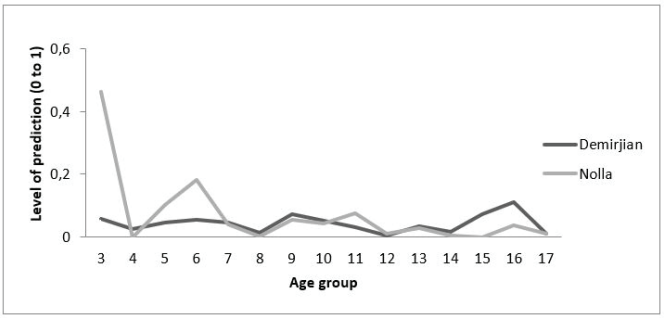


Figure 2. *The prediction levels in the Demirjian and Nolla methods by age group.*

Figure 4. *The provinces where dental age determination has made on the map of Turkiye.*

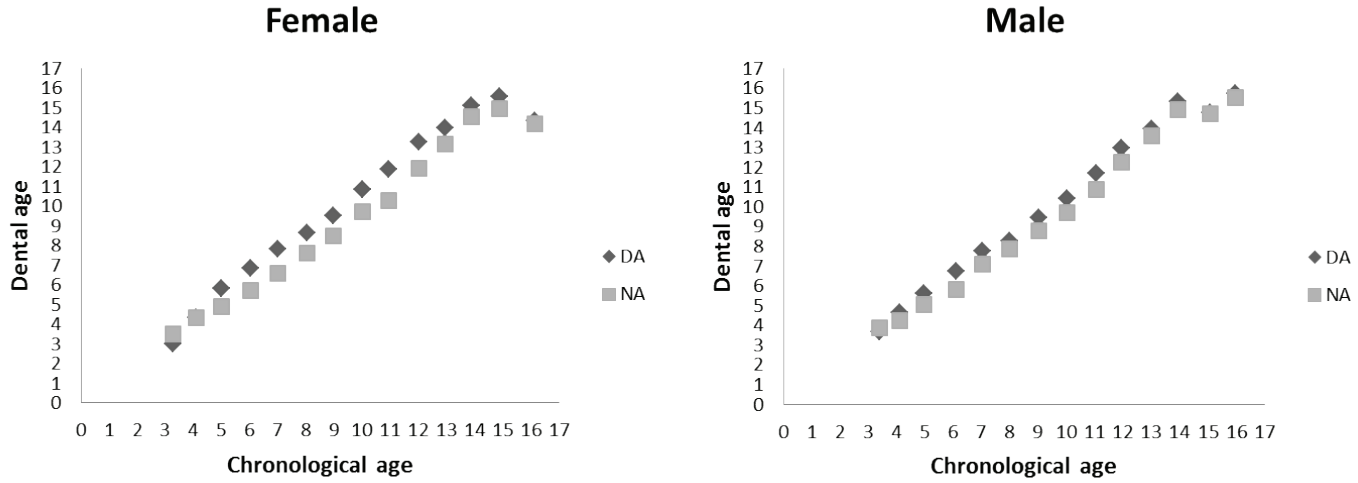


Figure 3. *The correlation between dental age and chronological age (DA: Demirjian Age, NA: Nolla Age).*

Nolla's (17) methods for assessing the easthern Turkish population. In this study, we also emphasized and evaluated male and female differences, and age differences. This radiological dental age assessment study on a large population of people in Eastern Turkey can shed light on the age determination methods that can be applied in this region.

The age determination methods should be evaluated separately for male and female participants. Since physiological development and dental development are compatible with each other and male and female physiological development is different, individuals were divided into two groups according to gender while performing an evaluation in this study (16, 17). In this study, the mean difference between the

Table 5: *Studies conducted in Turkey about age estimation by Demirjian and Nolla methods.*

	Localization	Altitude	n	Age (years)	Male		Female	
					The mean difference between the chronological and dental ages ranged	The mean difference (chronological and dental ages)	The mean difference between the chronological and dental ages ranged	The mean difference (chronological and dental ages)
Demirjian								
The present study	Eastern Turkey (Malatya)	970 m	1587	3-17.9	-1.92 to 1.42 years	0.61 years	-3.07 to 1.23	0.75 years
Altunsoy et al. (1)	Western Turkey (İzmir)	25 m	635	7-16	0.10 to 0.76 years	0.52 years	0.28 to 0.87 years	0.56 years
Tunc et al. (23)	Northern Turkey (Samsun)	4 m	900	4-12	0.36 to 1.43 years		0.50 to 1.44 years	
Nur et al. (14)	Northeastern Turkey (Trabzon)	37 m	673	5-15.9	0.27 to 1.60 years	0.84 years	0.15 to 1.24 years	0.89 years
Mentes et al. (22)	(İstanbul)		419	5-11.9	0.18 to 0.54	0.39 years	-0.07 to 0.73	0.30 years
Celikoglu et al. (13)	Eastern Turkey (Erzurum)	1900 m	807	7-15	0.4 to 1.3 years	0.9 years	0.2 to 1.9 years	1.1 years
Cantekin et al. (15)	Eastern Turkey (Erzurum)	1900 m	471	7-14.9	-0.45 to 2 years	Central Anatolian population was dentally advanced compared with the Eastern Anatolian population. 0.91 years	-0.93 to 0.77 years	Central Anatolian population was dentally advanced compared with the Eastern Anatolian population. 0.81 years
	Central Turkey (Kayseri)	1071 m	473	7-14.9	0.70 to 3.15 years		0.24 to 1.28 years	
	Total		944	7-14.9		0.87 years		0.45 years
Kirzioglu et al. (9)	Western Turkey (Isparta)	1043 m	425	7-13	0.37 to 0.68 years	0.52 years	0.34 to 1.17 years	0.75 years
Celik et al. (11)	Southern Turkey (Hatay)	100 m	932	4-18	-1.02 to 1.69 years		-1.20 to 1.36 years	
Nolla								
The present study	Eastern Turkey (Malatya)	970 m	1587	3-17.9	-2.32 to 0.99 years	-0.001 years	-3.67 to 0.66 to years	-0.33 years
Miloglu et al. (10)	Eastern Turkey (Erzurum)	1900 m	719	6-18	0.0 to -0.6 years	-0.2 years	-0.1 to -1.0 years	-0.5 years
Nur et al. (14)	Northeastern Turkey (Trabzon)	37 m	673	5-15.9	-0.01 to -0.93 years	-0.50 years	-0.01 to -0.94 years	-0.57 years
Kirzioglu et al. (9)	Western Turkey (Isparta)	1043 m	425	7-13	-0.54 to 0.25 years	-0.53 years	-0.67 to 0.27 years	-0.57 years

CA and the dental age according to the Demirjian method ranged from -3.07 to 1.23 years (mean: 0.75) in females and -1.92 to 1.42 years (mean: 0.61) in males. Similarly, the results from other studies, used the Demirjian method, supported that the dental age assessment performed by the Demirjian method shows more value than the chronological age. These studies showed the following results (range): 0.14 to 2.79 in a Serbian population (24); -0.1 to 1.15 (0.75) years in females, -0.22 to 0.80 (mean:0.49) years in males in a South Australia population (25); 0.28 to 0.87 years in females, 0.10 to 0.76 years in males in a western Turkish population (1); 0.50 to 1.44 years in females and 0.36 to 1.43 years in males

in a northern Turkish population (23). In a study conducted in Saudi Arabia, the ages were overestimated by 0.3 years in males and 0.4 years in females (26). In another study from Saudi Arabia, the Saudi boys were 0.57 years, and girls were 0.44 years ahead of their chronological ages (27).

In the dental age assessment performed by the Nolla method, it was shown in the studies that it exhibits a lower value than chronological age (10, 14, 28). Miloglu *et al.*'s (10) study which was done in the east of Turkey by using the Nolla method, dental age was calculated 0.5 years lower in females and 0.2 years lower in males than chronological age. In an another study conducted in the north of Turkey with the Nolla method, dental age was found to be 0.57 years lower in females and 0.50 years lower in males compared to the actual chronological age (14).

In a study conducted in the south of Turkey, dental age indicated an underestimation of 0.53 and 0.57 years for males and females, respectively, according to the Nolla method, and an overestimation of 0.52 and 0.75 years for males and females, respectively, according to the Demirjian method (9). Similarly, in our study, there was an overestimation of 0.61 years for males and 0.75 years for females according to the Demirjian method, while there was an underestimation of 0.32 years for females and 0.003 years for males according to the Nolla method. The dental development was more advanced in girls than in boys, and this result is consistent with others (1, 9, 13-15, 25).

The differences between the studies can be caused by climate conditions, nutrition, and socioeconomic level (29). In addition, the studies conducted in Turkey were carried out especially in geographic areas that exhibit significant altitude differences. Previous studies have also demonstrated differences between geographical areas and cities within the same country (11, 15). Turkey, affected by different climates, is surrounded by the sea on three sides and also has one of the highest altitude cities of the world, namely Erzurum. The Turkish studies are presented in Table 5, and the results show how effective geographic differences could be in tooth development. For example, Miloglu *et al.* (10) conducted the study in the highest altitude region of Turkey (altitude = 1900 m, which is one of the highest altitude regions in the world), Altunsoy *et al.* (1)' study included participants who live at an altitude of 25 m, Nur *et al.* (14) at 37 m, Kirzioglu *et al.* (9) at 1043 m, while the present one at 970 m. Although our study was conducted in the eastern area which is similar to the Miloglu *et al.* (10), the altitude in that province was much lower than that of the Erzurum province. The altitude is an important parameter affecting climatic conditions, and causes changes in human biological structure and is thought to be a factor that should be evaluated in terms of dental development. Cantekin *et al.* (15), comparing eastern Anatolia (altitude: 1900 m) and Central Anatolia (altitude: 1054 m), suggested that regional conditions could affect dental maturation. The results of our study were consistent to that of the the Kirzioglu *et al.*'s study (9). According to the Demirjian method, the overestimation was 0.61 years for males and 0.75 years for females in our study (altitude=970 m), and 0.52 years for males and 0.75 years for females in Kirzioglu *et al.*'s study (altitude=1043m).

As girls have precocious puberty compared to boys, the physiological age of girls is mostly older than boys (15). In our study, the difference between the dental age and chronological age of females (0.75 years) was found to be higher than that of males (0.61 years) in the assessment made with the Demirjian method.

Altunsoy *et al.* (1), Celikoglu *et al.* (13), and Kirzioglu *et al.* (9) from Turkey reported that Demirjian method was not suitable for Turkish population. Nolla's method was found to be more accurate than Demirjian method (14). In an another study from Turkey, the accuracy of this method (Nolla) was reported to be acceptable for boys, which is in consistent with our findings, but it was not suitable for girls (10). In the present study, we found that Nolla method was more accurate than Demirjian method, and more suitable for boys.

Tomas *et al.* (12) stated that for chronological age the predictive capacity of the Nolla method was 64.4% and the predictive capacity of the Demirjian method was 47.5%. In our study, the chronological age predictive capacity of the Nolla method was found to be 77% and the predictive capacity of the Demirjian method was 74%. Also, comparison of the gender indicated that the predictive capacity in males was greater than in females, for both methods. There are some limitations in this study. First, dental development does not depend solely on the ethnicity, as there are other variables such as nutrition, familial factors, genetic, lifestyle, hormonal state, all of which could be expected to affect dental development. In the present study, however, all these factors could not be examined. Secondly, although individuals with known systemic problems had been excluded from the study, there may be a possibility that undiagnosed ones may have participated in the study. On the other hand, although the number of children aged 3 and 17 was small, the large sample size was the strongest aspect of the present study, and this was the main difference from the previous studies conducted on a Turkish sample by using the same methods. No other studies had as many samples as this study did. In addition, these two methods, which are widely used in our country and in the literature to evaluate the tooth development, were preferred to estimate the chronological age, considering that the results of the study could be compared.

Conclusion

The Nolla and Demirjian methods can be applied to Turkish children for the estimation of chronological age with an approximate error of 25%. But it is worth noting that the Nolla method was found to be more accurate than the Demirjian method in our sample. Both methods are sensitive to gender and age. The correction factors must be established to make the Demirjian and Nolla methods applicable to each population. The authors of the present study suggest that the Nolla method should be preferred primarily for estimating the chronological age of the child population in Turkey.

Türkçe Özet: *3-17 Yaş Arası Türkiye'nin Doğusundaki Çocuklarda Demirjian ve Nolla Yöntemlerine Göre Yaş Tahmininin Doğruluğu. Amaç: Diş yaşı değerlendirmesi, suç, adli tıp ve antropolojik amaçlar için kullanılan en güvenilir kronolojik yaş tahmini yöntemlerinden biridir. Bu çalışma, cinsiyet ve yaş grubu değişkenlerine göre bir Türk örnekleminde Nolla ve Demirjian yöntemleriyle ölçülen diş yaşına bakarak kronolojik yaşın tahmin edilmesinin ne kadar doğru olduğunu belirlemeyi amaçlamaktadır. Gereç ve Yöntem: 3-17 yaşları arasındaki 1587 deneğin (774 kadın ve 813 erkek) panoramik radyografileri üzerinde retrospektif bir*

çalışma gerçekleştirildi. Demirjian ve Nolla yöntemlerine göre ortalama diş yaşı, ortalama kronolojik yaş (KY) ile karşılaştırıldı. Ayrıca, KY tahmininin yüzde değeri her iki yöntem kullanılarak belirlendi. Bulgular: Nolla yöntemi kullanılarak kronolojik yaşın düşük tahmin edildiği (erkek -0,003, kadın -0,32, her ikisi -0,16) ve Demirjian yöntemi kullanılarak kronolojik yaşın yüksek tahmin edildiği (erkek +0,61, kadın +0,75, her ikisi de +0,68) gözlemlendi. Sonuç: Türkiye'nin doğusundaki nüfusta KY tahmininde Nolla yöntemi Demirjian yönteminden daha doğruydu. Anahtar kelimeler: Nolla yöntemi, Demirjian yöntemi, diş yaşı, kronolojik yaş, Türk çocukları

Ethics Committee Approval: The study was approved by the Non-Interventional Clinical Research Ethics Committee of Inönü University, Malatya, Turkiye (2020/856).

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: GD, TPGO, SD participated in designing the study. GD, TPGO participated in generating the data for the study. GD, TPGO participated in gathering the data for the study. GD participated in the analysis of the data. GD, TPGO wrote the majority of the original draft of the paper. GD, TPGO participated in writing the paper. GD, TPGO, SD have had access to all of the raw data of the study. GD, TPGO, SD have reviewed the pertinent raw data on which the results and conclusions of this study are based. GD, TPGO, SD have approved the final version of this paper. GD, TPGO, SD guarantee that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they did not receive any financial support.

References

1. Altunsoy M, Nur BG, Akkemik O, Ok E, Evcil MS. Applicability of the Demirjian method for dental age estimation in western Turkish children. Acta Odontol Scand 2015;73:121-5. [CrossRef]
2. Cameriere R, Flores-Mir C, Mauricio F, Ferrante L. Effects of nutrition on timing of mineralization in teeth in a Peruvian sample by the Cameriere and Demirjian methods. Ann Hum Biol 2007;34:547-56. [CrossRef]
3. Panchbhai A. Dental radiographic indicators, a key to age estimation. Dentomaxillofac Radiol 2011;40:199-212. [CrossRef]
4. Mohammed RB, Sanghvi P, Perumalla KK, Srinivasaraju D, Srinivas J, Kalyan US, et al. Accuracy of four dental age estimation methods in southern Indian children. J Clin Diagn Res 2015;9:HC01. [CrossRef]
5. Moorrees CF, Fanning EA, Hunt Jr EE. Age variation of formation stages for ten permanent teeth. J Dent Res 1963;42:1490-502. [CrossRef]
6. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. Forensic Sci Int 1995;74:175-85. [CrossRef]
7. Haavikko K. Tooth formation age estimated on a few selected teeth. A simple method for clinical use. Procc Finn Dent Soc 1974;70:15-9.
8. Liliequist B, Lundberg M. Skeletal and tooth development: a methodologic investigation. Acta Radiol Diagn 1971;11:97-112. [CrossRef]
9. Kirzioglu Z, Ceyhan D. Accuracy of different dental age estimation methods on Turkish children. Forensic Sci Int. [Comparative Study]. 2012;10;216:61-7. [CrossRef]
10. Miloglu O, Celikoglu M, Dane A, Cantekin K, Yilmaz AB. Is the assessment of dental age by the Nolla method valid for eastern Turkish children? J Forensic Sci 2011;56:1025-8. [CrossRef]
11. Celik S, Zeren C, Celikel A, Yengil E, Altan A. Applicability of the Demirjian method for dental assessment of southern Turkish children. J Forensic Leg Med 2014;25:2-6. [CrossRef]
12. Tomás LF, Mónico LS, Tomás I, Varela-Patiño P, Martin-Biedma B. The accuracy of estimating chronological age from Demirjian and Nolla methods in a Portuguese and Spanish sample. BMC Oral Health 2014;14:160. [CrossRef]
13. Celikoglu M, Cantekin K, Ceylan I. Dental age assessment: the applicability of Demirjian method in eastern Turkish children. J Forensic Sci 2011;56:S220-S2. [CrossRef]
14. Nur B, Kusgoz A, Bayram M, Celikoglu M, Nur M, Kayipmaz S, et al. Validity of Demirjian and Nolla methods for dental age estimation for Northeastern Turkish children aged 5–16 years old. Med Oral Patol Oral Cir Bucal 2012;17:e871. [CrossRef]
15. Cantekin K, Sekerci AE, Peduk K, Delikan E, İlday NO, Demirbuga S, et al. Dental age assessment for different climatic regions. Am J Forensic Med Pathol 2014;35:197-200. [CrossRef]
16. Demirjian A, Goldstein H, Tanner J. A new system of dental age assessment. Hum Biol 1973:211-27.
17. Nolla CM. The development of permanent teeth: University of Michigan; 1952.
18. Corral C, García F, García J, León P, Herrera A, Martínez C, et al. Chronological versus dental age in subjects from 5 to 19 years: a comparative study with forensic implications. Colomb Méd 2010;41:215-23. [CrossRef]
19. Willems G, Van Olmen A, Spiessens B, Carels C. Dental age estimation in Belgian children: Demirjian's technique revisited. J Forensic Sci 2001;46:893-5. [CrossRef]
20. Sukhia RH, Fida M, Azam SI. Dental age table for a sample of Pakistani children. Eur J Orthod 2010;34:77-82. [CrossRef]
21. Uysal T, Yagci A, Ramoglu SI. Dental maturation in patients with unilateral posterior crossbite. World J Orthod 2009;10:383-8.
22. Mentes A, Ergeneli S, Tanboga I. Applicability of Demirjian's standards to the Turkish children's dental age estimation. J Marmara Univ Dent Fac 2000;4:63-8.
23. Tunc ES, Koyuturk AE. Dental age assessment using Demirjian's method on northern Turkish children. Forensic Sci Int 2008;175:23-6. [CrossRef]
24. Djukic K, Zelic K, Milenkovic P, Nedeljkovic N, Djuric M. Dental age assessment validity of radiographic methods on Serbian children population. Forensic Sci Int 2013;231:398. e1-. e5. [CrossRef]
25. Flood SJ, Franklin D, Turlach BA, McGeachie J. A comparison of Demirjian's four dental development methods for forensic age estimation in South Australian sub-adults. J Forensic Leg Med 2013;20:875-83. [CrossRef]
26. Al-Emran S. Dental age assessment of 8.5 to 17 Year-old Saudi children using Demirjian's method. J Contemp Dent Pract 2008;9:64-71. [CrossRef]
27. Alassiry A, Alshomrani K, Al Hasi S, Albasri A, Alkhathami SS, Althobaiti MA. Dental age assessment of 3-15-year-old Saudi children and adolescents using Demirjian's method-A radiographic study. Clin Exp Dent Res 2019;5:336-42. [CrossRef]
28. Kurita LM, Menezes AV, Casanova MS, Haiter-Neto F. Dental maturity as an indicator of chronological age: radiographic assessment of dental age in a Brazilian population. J Appl Oral Sci 2007;15:99-104. [CrossRef]
29. Koshy S, Tandon S. Dental age assessment: the applicability of Demirjian's method in south Indian children. Forensic Sci Int 1998;94:73-85. [CrossRef]

eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2022; 56(2): 88-95

Original research

Future expectations, career choices and related factors among dental students: A cross-sectional study

Gulaiym Batyrbekova[1], Tulin Coban[2], Canan Hekimoglu[1], Dilek Yıldırım Pak[2], Merve Büke Şahin[2], Mustafa Baris Guncu[1], Banu Cakir[2]

Purpose
The aim of this study was to determine descriptive characteristics of dental students, to investigate their professional expectations, career decision criteria, and related factors; to examine how (if any) seniority in school affects these.

Subjects and Methods
During the period of 2018-2019, all 1-5 grade students (n = 754) of Hacettepe University Dental School were invited to participate and those who accepted had filled under observation a standard questionnaire form of 35 questions (83.4%). In the analysis of the data, descriptive statistics, chi-square, Student's t-test and ANOVA and Odds ratio methods were used.

Results
In this cross-sectional study, 66% of the group were female, age range was 18-30 (mean±SD= 21.2 ± 1.7). The most common reasons for choosing dentistry were "financial benefits", "job security" and "professional status". "Undertake specialist training" (80.2%) was the most common short-term expectation after graduation; two most common long-term expectations were "having a private clinic" (57.9%) and "completing specialization training" (56.0%). The most important factors affecting the post-graduation working plans were work-life balance and economic stability.

Conclusion
It is recommended to provide adequate counseling and guidance to students about potential career paths to maximize a balanced and widely accessible oral health service delivery across the country with more motivated dentists. Qualitative research may improve our understanding of how dental education can be improved to fulfill students' expectations from school, and to motivate dental students towards general practitioning in the future.

Keywords: *Dental students, future expectations, career choice, influences, Turkiye*

Introduction

Dentistry is one of the leading professions offering healthcare services (1). Population growth, ageing and awareness of the importance of oral health have increased the need for the dental profession, imposing establishment of new dental schools. Universal prestige and respectability also appear to be predictors for young people choosing dentistry as a profession.

Dentistry is considered as a popular and profitable profession in many countries (2-6). Professional choices vary from one society to another, based on various factors such as gender, ethnic group, family and environmental characteristics, and parental educational attainment (2, 7). Professional knowledge, skills and experience gained over dental school years are likely to shape future expectations and career choices of dental students, and their professional satisfaction in years to come (8-11). Pro-

ORCID IDs of the authors: G.B. 0000-0001-7676-2309; T.C. 0000-0003-1665-129X; H.C.H. 0000-0003-4185-7900; D.Y. 0000-0001-8697-4372; M.B. 0000-0002-5132-8220; M.B.G. 0000-0001-6109-2218; B.C. 0000-0001-6645-6527

[1]*Department of Prosthodontics, Hacettepe University Faculty of Dentistry, Ankara, Turkiye*

[2]*Department of Public Health, Hacettepe University Faculty of Medicine, Ankara, Turkiye*

Corresponding Author: Gulaiym Batyrbekova

E-mail: gulaiymbatyrbekova@gmail.com

Received: 10 May 2021
Revised: 21 September 2021
Accepted: 12 November 2021

DOI: 10.26650/eor.2022932541

How to cite: *Batyrbekova G, Coban T, Hekimoglu C, Yildirim Pak D, Buke Sahin M, Guncu MB, Cakir B. Future expectations, career choices and related factors among dental students: A cross-sectional study. Eur Oral Res 2022; 56(2): 88-95. DOI: 10.26650/eor.2022932541*

fessional motivation of the dentists, together with the quality of the services provided to the society will increase in the ratio of meeting their expectations.

The majority of publications on future expectations and career choices of dentistry students are from developed countries (9, 12-15). Findings reveal that students' professional expectations and areas of specialization may vary depending on various factors: including professional, personal, and financial achievements, in short term; and, by professional development, work-life balance, and financial stability expectations for the long term (9, 13, 16). The collection of relevant data before graduation will enable better orientation to education, professional preparation, and will contribute to institutional plans and interventions to train highly motivated and successful dentists.

The aim of this study is to determine descriptive characteristics of dental students attending Hacettepe University Dental School, to investigate their professional expectations, career decision criteria, and related factors; and to further examine how (if any) seniority in school affect these. The long-term goal is to improve educational and professional counseling for dental students, starting early in school, to improve their motivation and satisfaction at school; and to enable them to choose the best practice plans suitable for themselves for their professional years to come.

Subjects and methods

Study population

A cohort study was planned for longitudinal follow-up of all students (n=754) of Hacettepe University, Faculty of Dentistry, Ankara, Turkey, enrolled in any class, as of October 2018. This cross-sectional analytical study provides data obtained at baseline. At the initiation of the study, the total number of enrolled students were 190, 145, 136, 153 and 130 in the 1st, 2nd, 3rd, 4th and 5th grades respectively.

Ethical approval and study questionnaire

Ethical approval was obtained from the Hacettepe University Non-Interventional Research Ethics Committee (24/10/2018 and 16969557-285) and verbal informed consents were obtained from each participant prior to the survey. All students were invited to participate in the study and those who attended the school over the data collection period completed the questionnaires, if they approved to do so. A standardized questionnaire was prepared and the pilot sample was tested on 20 students attending another dental school in the city. Revised questionnaires were distributed to students following/at the start of selected classes and were completed anonymously by participants under observation. No dental school faculty member was present at the time of the survey so that the students did not feel any pressure to participate in the study.

The questionnaire consisted of 35 multiple choice and open-ended questions, with 4 main sections; 12 questions were about sociodemographic characteristics, 8 questions about their vision of dental education, and the final 15 questions were about students' short-term (next 5 years) and long-term (20 years later) future expectations.

Statistical analysis

Statistical analysis included descriptive statistics (frequency and percent distribution: average/mean, standard deviation/Q1, and Q3 values). Chi-square, exact chi-square, Student's t-test, and ANOVA analysis were used for comparison of groups, as appropriate to variable type. Odds ratios (95% confidence intervals) were calculated to evaluate potential associations. All analyses were conducted using SPSS ver. 23 software (SPSS inc. Chicago, IL, USA).

Results

Sociodemographic characteristics

The survey was completed by 83.4 % of the 754 students enrolled in the Faculty of Dentistry in the 2018-2019 academic year. Of these, 414 were women (66%), 618 were single (98.7%) and 605 were Turkish citizens (96.6%). Of all participants, 3.7% were from Iran, Azerbaijan, TRNC, Afghanistan, Albania, Bulgaria, Palestine, Ghana, South Korea, Kenya, Mongolia and Uzbekistan.

The age range of the participants was 18-30 years (mean 21.1, SD 1.7 years). About three fourths of the students knew a second language. The most commonly spoken foreign languages were English 452 (71.9%) and German 55 (8.7%).

About half of the mothers (n=300) and 63.9% of the fathers (n= 399) had university degrees or higher. Sixty-one mothers and 62 fathers, had reportedly a profession in the health sector. The number of students who had a dentist in the immediate environment was 208 (33.2%); and 42.6% of those were relatives. Having a hobby was pretty common (86.9%), yet, only 64.2% (n=400) reported to have enough spare time for their hobbies. Of the several hobbies reported, the most common ones were sports (50.1%), reading books/science/writing (28.2%), music/singing/playing a musical instrument (26.7%) and going to movies (21.3%) (Table 1).

Perspective of dental education

In the national university entrance exam, reportedly, dental school was the first choice of 68.2% of dental students, the second or third choice of 12.8% students, and the 4th choice of 13% students. The top three most frequently mentioned reasons for choosing dental school were "financial benefits", "job security" and "professional status". Three hundred and ninety-nine (63.6%) participants positively replied to the question "If you had a chance to choose today, would you prefer dentistry again?"; and 106 (16.9%) respondents answered "no" to the same question. The latter students stated the reason for that as "the education is difficult/tiresome/backbreaking". Two hundred and seventy-two (43.6%) students had thought at least once about dropping out of school; women were significantly more likely to do so [OR=1.54 (95%CI= 1.09-2.16)]. Just over half of the students (56.9%) stated that the education provided by the school met their professional expectations. And only one-fifth of participants had adequate information about different career paths they would have upon graduation; interestingly, the last year students claimed so, with a rate lower (9.8%) than that in all other classes (Table 2).

Table 1: *Descriptive characteristics of dental students.*

Characteristic	Grade										p value
	First		Second		Third		Fourth		Fifth		
	n	%	n	%	n	%	n	%	n	%	
Gender (n=627)											
Female	100	61.3	74	62.2.	74	71.8	94	65.7	72	72.7	0.206
Male	63	38.7	45	37.8	29	28.2	49	34.3	27	27.3	
High School (n=626)											
Anatolian High School	67	41.4	51	42.9	56	54.4	88	61.5	67	67.7	**<0.001**
Science High School	56	34.5	37	31.1	19	18.4	18	12.6	14	14.1	
Regular High School	39	24.1	31	26.0	28	27.2	37	25.9	18	18.2	
Mothers' education level (n=624)											
High School or less	80	50.0	60	50.4	53	51.5	75	52.4	56	56.6	0.897
University graduate	67	41.9	50	42.0	42	40.8	62	43.4	38	38.4	
Postgraduate degree	13	8.1	9	7.6	8	7.7	6	4.2	5	5.0	
Fathers' education level (n=624)											
High School or less	56	34.8	45	37.8	38	37.3	46	32.2	40	40.4	0.313
University graduate	71	44.1	59	49.6	49	48.0	79	55.2	48	48.5	
Postgraduate degree	34	21.1	15	12.6	15	14.7	18	12.6	11	11.1	
Mothers' occupation (n=623)											
Health sector	21	13.0	10	8.5	7	6.8	11	7.7	13	13.1	0.089
Other	61	37.9	60	50.8	40	38.8	69	48.6	37	37.4	
Retired/ Never worked	79	49.1	48	40.7	56	54.4	62	43.7	49	49.5	
Fathers' occupation (n=623)											
Health sector	16	10.0	13	11.0	9	8.9	14	9.8	8	8.1	0.088
Other	101	63.1	80	67.8	57	56.4	89	62.2	49	49.5	
Retired/ Never worked	43	26.9	25	21.2	35	34.7	40	28.0	42	42.4	
Spare time for hobbies (n=623)											
Always	41	25.6	11	9.3	16	15.5	13	9.1	5	5.1	**<0.001**
Sometimes	91	56.9	57	48.3	53	51.5	68	47.6	45	45.4	
Rarely	26	16.3	42	35.6	29	28.2	51	35.7	44	44.4	
Never	2	1.2	8	6.8	5	4.8	11	7.7	5	5.1	

Short-term career expectations

About four-fifths of the participants, being higher among women, wanted to continue a specialty training in the next 5 years. Within 5 years, 33.5% wish to work in abroad (33.5%), another 33.0% want to start up a private clinic and 28.8% want to work in a private clinic (28.8%). Women were less likely than men to initiate a private clinic of own [OR= 0.59 (95% CI= 0.42-0.84)]. Having a private clinic of his/her own was the most common among grade 1 students and was about one-fourth (95 CI= 0.14-0.50) of those among grade 5 students (Figure 1).

Long-term career expectations

The most common long-term expectations were having a private clinic (57.9%), completing specialization training (56.0%), attaining high economic income (49.3%), and working in a platform where professional skills can be improved (44%, 5). Women wanted to complete their specialization training 1.7 times more than men and 1.6 times more wanted to work in a platform where professional skills can be improved (Figure 2). The wish to have a private clinic was the highest among first-year dental students and decreased significantly from first grade to fifth grade (71.0% -54.1%) (Figure 2).

Five hundred and thirteen (82.5%) participants found specialization necessary after graduation. Not all wants it for a career but want to get a specialty training to gain further experience in a particular area (76.5%), to continue to work in a more specific area (59.0%) and to get higher income (46.6%). Orthodontics (61.4%), oral and maxillofacial surgery (39.7%), prosthodontics (34.8%), periodontology (30.9%), and pedodontics (27.0%) were the most preferred branches of specialization. Women wanted the restorative dentistry 3 times and pedodontics 2 times than that reported by men.

Table 2: *Professional choices and related factors.*

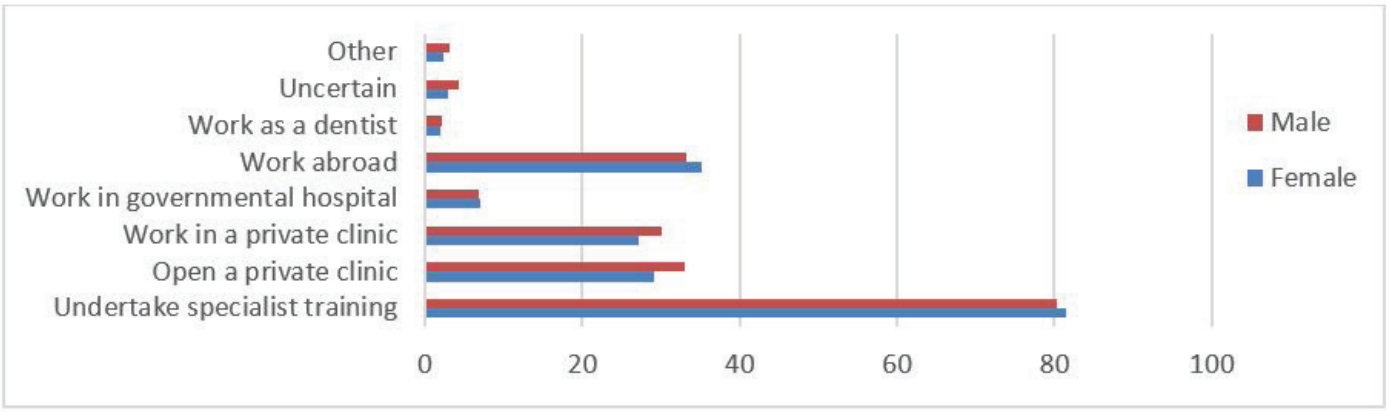
	Number	Percentage
Order of choosing the faculty of dentistry in university exam		
First choice	426	68.2
Other*	198	31.8
Reasons for choosing dentistry		
Financial benefits	390	62.2
Job security/ high levels of demand for dentists	346	55.2
Professional status	294	46.9
Personal interest in dentistry/ ideal	248	39.6
Personal experiences/ Being affected by the dentist during dental treatments	156	24.9
Interest in a healthcare profession and getting score appropriate for dentistry	109	17.4
Family's recommendation	85	13.6
Due to presence of a dentist in the family or in the immediate environment	64	10.2
Other**	53	8.5
Whether they would prefer dentistry again (if there is a chance to choose today)		
Yes	399	63.6
No	106	16.9
Undecided	122	19.5
The reasons for those who would prefer again (n= 338)		
I love / want to do dentistry / I am happy / pleasant	156	46.2
My dream / ideal job	48	14.2
It suits me / it meets my expectations	47	13.9
Other reason	87	25.7
The reasons for those who would not prefer again (n=91)		
Difficult/ Tiresome/ Backbreaking	41	45,1
No comment	26	28.5
Other reason	24	26.4
Presence of a dentist in their immediate environment		
Yes/ I have at least one	208	33.2
No/ I do not have	418	66.8
Proximity state of the dentists for the ones who replied yes to the previous question		
Relative	89	42.6
Family friend	56	26.8
Nuclear family	38	18.2
Other*	26	12.4
To what extent did education at school meet your professional expectations you had when you entered school?		
"Much better than I expected"	27	4.3
"Better than I expected"	79	12.6
"As I expected"	248	40.0
"Worse than I expected"	160	25.7
"Did not meet my expectations	55	8.8
No idea	41	6.6
"More difficult than I expected"	6	1.0
Other*	6	1.0
Have you ever thought about dropping out of school?		
Yes	272	43.6
No	352	56.4

The odds of reporting oral and maxillofacial surgery was 2 times in men than in women. The distribution of the branches of specialization that the students intend to choose varied by grade. Orthodontics was the most preferred specialty program among the first-year students, while this number decreases in the last year students ($p < 0.001$). Endodontics were reported mostly by second- and third-year students, reporting was statistically significantly lower in both the first year and fourth and fifth ($p < 0.001$). Popularity of periodontology increased by the increase in grade, with a significant trend test ($p < 0.001$). Prosthodontics was mostly reported by the first-year students, and its popularity decreases by seniority (Figure 3).

Of all the students, 312 wanted to pursue an academic career. By pursuing an academic career, they expect to be in a platform where they can closely follow professional developments (68.5%), to make contributions to science (53.5%), to raise students (43.2%), and to be respected more in the society (23.0%). Students mostly want to practice their profession in a metropolitan city (88.3%) and to work in private sector (75.7%) or university hospitals (47.8%). Figure 4 presents that students preference of the place they want to work in the future vary by grade the students currently attend. Wish to work in a university hospital increases significantly towards graduation and is higher among women; whereas, men want to work in public hospitals more. The popularity of working in private sector is the highest among the first-year students. (Figure 4). When deciding on the type of institution to work for, participants considered mostly economic opportunities (76.6%) and sufficient professional knowledge and experience (75.2%).

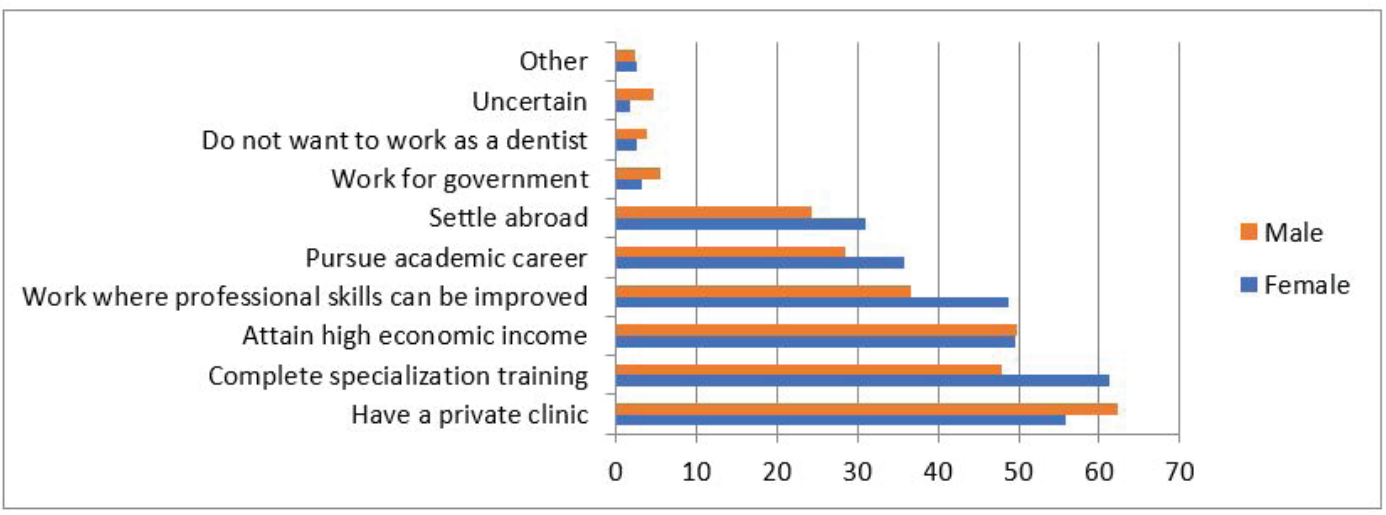
When deciding on the post-graduate working plan, most of the participants care for the work-to-private life balance (79.7%), economic stability (60.3%) and developing professional skills (57,7%). Women preferred the "work-private life balance" 1.5 times more than men. Considering the working time, 52.8% of the participants wanted to work full time (8 hours) and 22.9% wanted to work part-time.

When asked about the difficulties of the dentistry as a profession; economic difficulties in providing materials (71.0%) was the most frequently mentioned answer. The most challenging aspect of the profession according to students was "satisfying patients with the dental service provided" and it was 1.76 times (95% CI= 1.24-2.48) times more challenging for males. For men, the most compelling aspect of the profession was financial management [1.80 (95% CI=1.28-2.53)]. Communicating with patients was found to be a more challenging part for men participants; the odds was 1.41 times (95% CI=1.00-1.99) than in women. As the best feature of this profession; the most frequent answers listed by students were flexible working hours (65.3%), high-income opportunity (65.2%) and helping patients (64.6%). Most of the



* Respondents could choose more than one option.

Figure 1. *Distribution of students' expectations in the short term (within 5 years) by gender.*



* Respondents could choose more than one option.

Figure 2. *Distribution of students' expectations in the long term (after 20 years) by gender.*

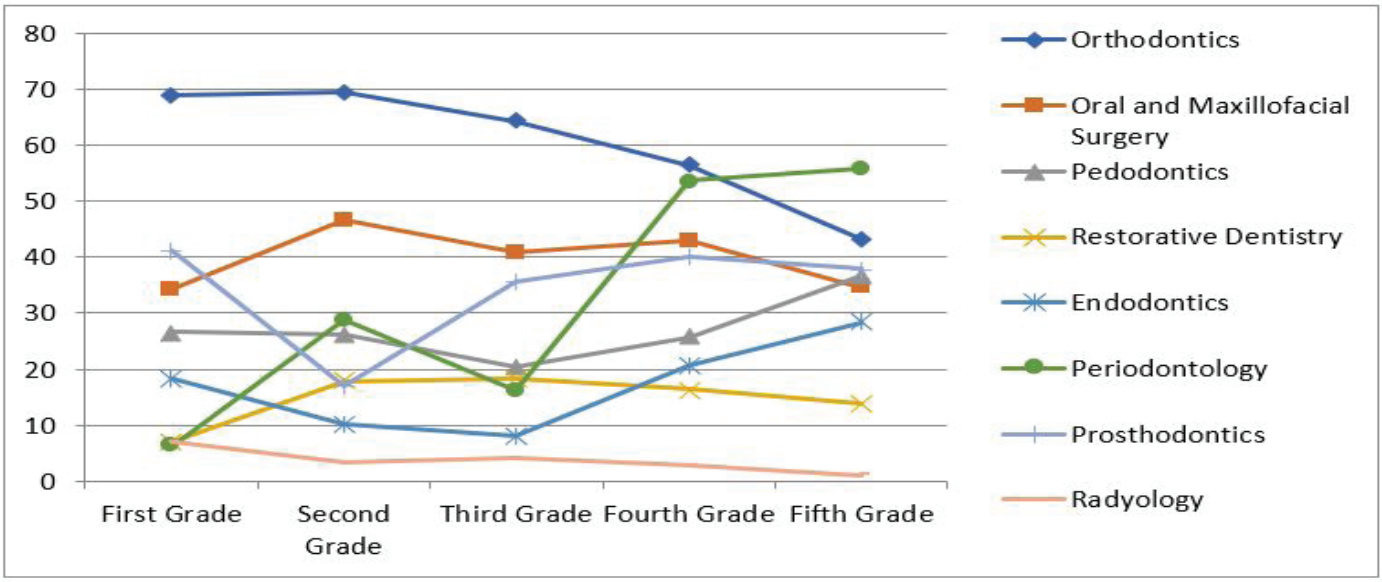
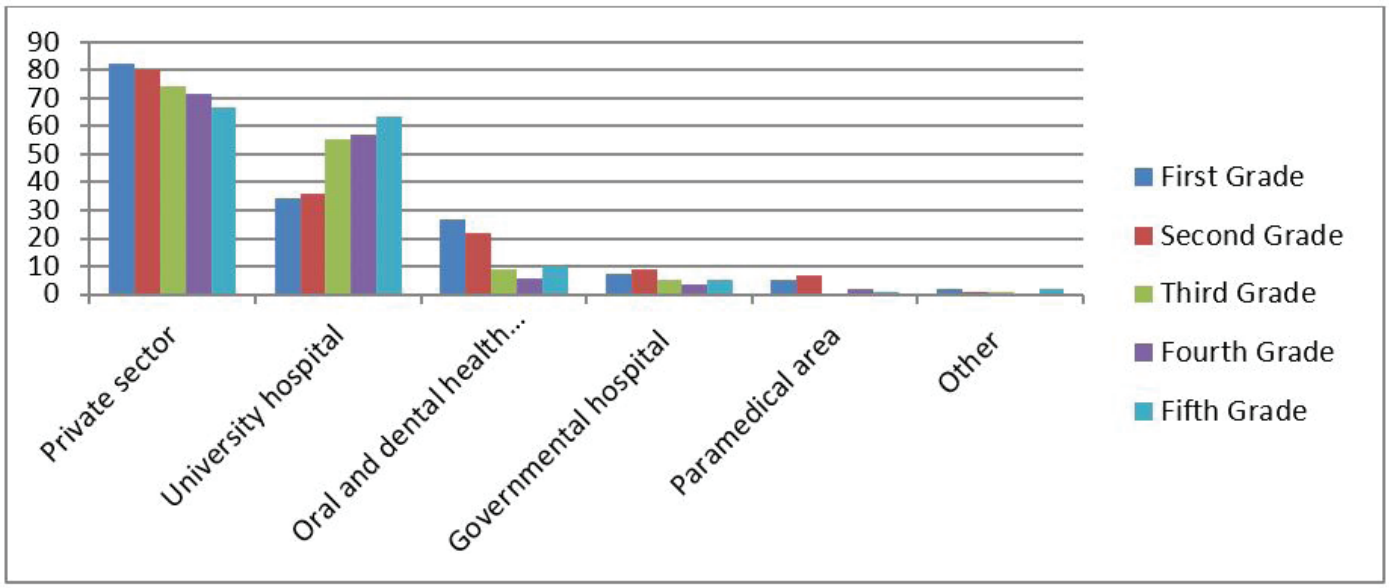


Figure 3. *Distribution of popular specialty branches among students by grade.*



* Respondents could choose more than one option.

Figure 4. *Distribution of the institutions students want to work in the future.*

female students (68.0%) consider the best feature of dentistry as helping patients, while men cared for the potential for high-income (71.4%).

Discussion

This is the first study from Turkey, which primarily studies the underlying factors for choosing a dental school, whether the students are satisfied with the curriculum and their gainings from dental school and what their future career plans are. There are several studies that focus on these issues and indicate the underlying factors for career decisions in developed countries (2,5,8-13,17). However, in developing countries, such as ours, the individual, familial and environmental factors that could be linked with career plans are not so definite. We hope that our study can be informative for other developing countries, as well. Another asset of the study is the ability to compare and contrast students from different levels of classes, which may illustrate a cohort effect (if any). Our findings suggested that rather than a cohort effect, students' learnings in time about the different skills they need, difficulties and benefits of different specialty branches, conditions of working environments etc. may change their primary expectations at the entrance to school towards graduation. A previous study found that senior students were reported to give more realistic forward-looking answers about choosing an area of specialization (12). This may be an explanation to our finding of differences across grades. We hope to continue following these students, thorough graduation (up to five years), which may clarify the issues that cause differences across grades.

Sociodemographic and familial characteristics of the participants were in line with findings of earlier studies. The vast majority of the participants were female students, which is similar to the studies that determined the increased female ratio (17, 18). It has been reported that women generally pre-

fer dentistry over men because of the flexibility of working hours, which provides the opportunity to allocate time for their families and children (17, 19, 20). The most of the participants come from educated families, similar to findings of earlier studies (3, 14, 15, 19). Our finding of having a dentist in the immediate environment suggest that relatives or role models are likely to have an impact on career selection decision, as it is true in many developing countries (2, 17).

About 70% of all participants reported that dentistry was their first choice during university matriculation examination, which showed a similar result with the study conducted in Ireland. Dentistry was the first choice for 2/3 of dental school students in Ireland (21). Mostly, the positive working conditions of this profession, the desire to help people, and the opportunity of improving patients' appearances were attractive. In the study, some students (17,4%) stated that they chose dentistry as "they wanted to choose a profession (medicine) related to health and their score was appropriate (for dentistry, that is less than for medicine)". This is also in line with the findings of earlier studies, suggesting dentistry is chosen as an alternative for medicine (14, 21, 22).

When the reasons for choosing dentistry as a profession are investigated, it is stated that it is chosen mostly due to high income, regular working hours, the prestige of the profession, work-private life balance, quality of life (2, 3, 5, 23). In the findings of this study, it was found that students chose dentistry for almost the same reasons. The most frequently stated reasons were "high income", "a high chance of finding a job in the future- job security" and "professional status". However, if there was a chance to choose again, the participants who would consider choosing this profession again are only 63.6%. This result may be related to the intensity of work and taking on early responsibilities in the preclinical and clinical hours throughout the educational process. Findings similar to this result are shown in the study by Gallagher 2008 (5).

The mostly indicated expectation of students for the next 5 years was to become a specialist in a specific area. Earlier we had doctoral programs following dental school, and specialization programs have been initiated recently; this has become popular among dentists to be. The demand for specialists in dentistry is increasing and the fee for the work performed may be higher compared to those performed by the general practitioner dentist. Additionally, there is a desire of dental students to gain experience, to improve knowledge and skills in a certain area by undertaking specialist training. Another short-term expectation of the participants is achieving economic stability in the future. By completing the specialty training, they expect to earn more and have a high income in the future. Similar results have been found in studies in Malaysia, the United Arab Emirates, and Great Britain as well (9, 11, 12).

In the long-term prospects, participants wanted to have a private clinic, to complete their specialist training, and to have high economic income and to work in a platform where they can improve their professional skills. These expectations are mainly focused on economic benefits. This is also supported by the willingness of the participants to work in the private sector (75.7%). Due to the limited number of professional and material options available in public hospitals and the high number of patients examined per day, it is not preferred much (24). Institutions to be worked in the future differ by gender. We think that the reason for this may be the answer "sufficient professional knowledge and experience" 80.4% of female students gave to the question "What do you pay attention to when deciding on the institution you will work for?". It is possible to see that women give more importance to having professional knowledge and experience and pursue continuing education, thus, want to continue their professional lives in universities.

As a specialty training, orthodontics and oral and maxillofacial surgery have been the most popular areas. The same findings are indicated in another study conducted at a private university in Turkey (10). These two departments are also the most popular in dentistry worldwide, and the reason for this seems to be higher income (25).

The big cities are preferred by almost 90% of the participants to perform their profession. This finding may be due to greater job opportunities in big cities. Besides, students wish to keep the work-private life balance and economic stability. Gallagher *et al*. (13, 26) explored situations that play a role in career choices of dental students and new graduates in Great Britain and the results are similar. In this study, only one-fifth of the students answered positively to the question "Do you have any information about different career paths after graduation?". The remaining knew about career paths partially, insufficiently, or not at all. This issue warrants further research.

Conclusion

Students chose dentistry mostly for economic reasons and job security. They expect to complete specialist training and to secure economic stability in the short and long term. Big cities and private sector are highly popular among dental students. These findings suggest a potential for unbalanced distribution of dentists across the country in future years. Therefore, it is recommended to provide adequate counseling/training and guidance to students about potential career paths, starting from early years in school to maximize a balanced and widely accessible oral health service delivery across the country and to employ more motivated dentists in all sectors. It may also be valuable to inform high school students about the dental education for assisting them with conscious choice of profession. Qualitative research may improve our understanding of how dental education can be improved to fulfill students' expectations from school, and to motivate dental students towards general practitioning in the future.

Türkçe Özet: *Diş hekimliği fakültesi öğrencilerin meslek seçim özellikleri, gelecek beklentileri ve ilişkili faktörler: kesitsel bir çalışma. Amaç: Diş Hekimliği Fakültesindeki öğrencilerin bazı sosyodemografik özellikleri, meslek seçim nedenleri, meslekten beklentilerini ve bunlarla ilişkili faktörleri irdelemek, sınıflar arasındaki (varsa) farklılıkları belirlemek hedeflenmiştir. Yöntem: 2018-2019 döneminde, Hacettepe Üniversitesi Diş Hekimliği Fakültesi'ne kayıtlı tüm 1-5 sınıf öğrencileri (n=754) çalışmaya davet edilmiş ve katılmayı kabul edenler toplam 55 soru içeren standart bir anket formunu gözlem altında doldurmuşlardır (n= 629, %83,4). Verilerin analizlerinde, SPSS ver.23 istatistik paketi kullanılarak, tanımlayıcı istatistikler; Ki-kare, kesin ki-kare; Student's t-testi ve ANOVA analizleri ile, odds oranı hesaplamaları yapılmıştır. Bulgular: Kesitsel tipteki çalışmada grubun %66'sı kadın, yaş aralığı 18-30 (ortalama = 21,2 ± 1,7) yaştır. Bu mesleği seçimde etkili olarak en sık belirtilen 3 neden, diş hekimliğinin "maddi kazancı iyi", "ileride iş bulma şansı yük-*

sek" ve "toplumda saygın" bir meslek olmasıdır. Okuldaki eğitim, öğrencilerin %56,9'nun mesleki beklentisini karşılamaktadır. Öğrencilerin mezuniyet sonrası kısa dönem beklentilerin başında "bir branşta uzman olmak" (%80,2) gelmekte; en sık belirtilen iki uzun dönem beklentisi ise "özel klinik sahibi olmak" (%57,9) ve "uzmanlık eğitimini tamamlamak" (%56,0)'tır. Öğrencilerin %82,5'inin uzmanlığı gerekli bulması ve %75,7'inin özel sektörde çalışmak istemesi, mezuniyet sonrası kamuda çalışma isteği (%15,5) ile (%4,3) diş hekimliği dışında bir alanda çalışma yüzdelerinin benzer düşük boyutta olması dikkat çekicidir. Mezuniyet sonrası çalışma planını etkileyen en önemli faktörler iş-özel hayat dengesi ve ekonomik istikrardır. Öğrencilerin sadece beşte biri kariyer yolları hakkında "yeterli" bilgi sahibi olduğunu belirtirmiştir. Sonuç: Öğrencilere kariyer yolları hakkında erken dönemde yeterli danışmanlığın/eğitimin verilmesi ve yol gösterilmesi önerilmektedir. Sınıflar arasındaki farklılıkların izlenmesi için kohort izlemlerin yapılması değerli olacaktır. Öğrencilerin eğitim sürelerindeki beklentilerinin karşılanma yüzdesini artırmak, ileride kamuda çalışmasını ve pratisyenliği motive edecek faktörlerin belirlenmesi için niteliksel çalışmalar yararlı olacaktır. Anahtar kelimeler: Diş hekimliği, öğrenciler, meslek seçim nedenleri, mesleki beklentiler, kariyer yolları.

Ethics Committee Approval: Ethical approval was obtained from the Hacettepe University Non-Interventional Research Ethics Committee (24/10/2018 and 16969557-285).

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: GB, DY,MBG participated in designing the study. TC, MBG, BC participated in generating the data for the study. GB, TC, HCH, MB participated in gathering the data for the study. GB,TC, HCH, DY, MB, MBG, BC participated in the analysis of the data. GB wrote the majority of the original draft of the paper. GB,TC, HCH participated in writing the paper. GB,TC, DY,MB,BC have had access to all of the raw data of the study. GB, BC have reviewed the pertinent raw data on which the results and conclusions of this study are based. GB, TC, HCH, DY, MB, MBG, BC have approved the final version of this paper. GB guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they have received no financial support.

References

1. WHO. The World Health Report 2006 – working together for health.: World Health Organization; 2006.
2. Orenuga OO, da Costa OO. Characteristics and study motivation of clinical dental students in Nigerian universities. J Dent Educ 2006;70:996-1003. [CrossRef]
3. M Vigild ES. Characteristics and Study Motivation of Danish Dental Students in a Longitudinal Perspective. Eur J Dent Educ 2001;August 5:127-33. [CrossRef]
4. Khami MR MH, Jafarian M. Study motives and career choices of Iranian dental students. Med Print Pract 2008;17:221-6. [CrossRef]
5. Gallagher J, Clarke W, Wilson N. Understanding the motivation: a qualitative study of dental students' choice of professional career. Eur J Dent Educ 2008;12:89-98. [CrossRef]
6. Brand AA CU. Students' attitudes to dentistry in South African dental schools. J Dent Assoc South Afr 1997;52:713-20.
7. Mugonzibwa EA KE. Factors influencing career choice among high school students in Tanzania. J Dent Educ 2000;64:423-9. [CrossRef]
8. Kettler N, Frenzel Baudisch N, Micheelis W, Klingenberger D, Jordan AR. Professional identity, career choices, and working conditions of future and young dentists in Germany - study design and methods of a nationwide comprehensive survey. BMC Oral Health. 2017;17:127. [CrossRef]
9. Rashid HH, Ghotane SG, Abufanas SH, Gallagher JE. Short and long-term career plans of final year dental students in the United Arab Emirates. BMC Oral Health. 2013;13:39. [CrossRef]
10. Tanalp J, Ilguy D, Dikbas I, Oktay I. Demographic profile and future expectations of students enrolled in a Turkish private dental school. J Dent Educ 2012;76:800-9. [CrossRef]
11. Che Musa MF BE, Gallagher JE. Career expectations and influences among dental students in Malaysia. Int Dental J 2016;66:229-36. [CrossRef]
12. Gallagher JE, Patel R, Donaldson N, Wilson NH. The emerging dental workforce: why dentistry? A quantitative study of final year dental students' views on their professional career. BMC Oral Health. 2007;7:7. [CrossRef]
13. Gallagher JE, Patel R, Wilson NH. The emerging dental workforce: long-term career expectations and influences. A quantitative study of final year dental students' views on their long-term career from one London Dental School. BMC Oral Health. 2009;9:35. [CrossRef]
14. Gietzelt D. Social profile of first-year dentistry students at the University of Sydney. Aust Dent J 1997;42:259-66. [CrossRef]
15. Bedi R, Gilthorpe MS. Ethnic and gender variations in university applicants to United Kingdom medical and dental schools. Br Dent J 2000;189:212-5. [CrossRef]
16. Stewart FM, Drummond JR, Carson L, Hoad Reddick G. The future of the profession- a survey of dental school applicants. Br Dent J 2004;197:569-73; quiz 77. [CrossRef]
17. Weaver RG, Haden NK, Valachovic RW. U.S. dental school applicants and enrollees: a ten year perspective. J Dent Educ 2000;64:867-74. [CrossRef]
18. Vahid Dastjerdi M, Mahdian M, Vahid Dastjerdi E, Namdari M. Study motives and career choices of Iranian medical and dental students. Acta Med Iran 2012;50:417-24.
19. Brand AA, Chikte UM. Choosing dentistry as a career- Part I: A comparison of student motives. J Dent Assoc S Afr 1992;47:469-73.
20. Whittaker DK. Reasons for choice of dentistry as a career in applicants to a British dental school. Br Dent J 1984;156:23-5. [CrossRef]
21. Hallissey J, Hannigan A, Ray N. Reasons for choosing dentistry as a career--a survey of dental students attending a dental school in Ireland during 1998-99. Eur J Dent Educ 2000;4:77-81. [CrossRef]
22. Ohaeri JU AO, Falade GA. Beliefs and attitudes of clinical year students at Ogun State University concerning medical specialties. Nig Med J 1992;23:15-21.
23. Crossley ML, Mubarik A. A comparative investigation of dental and medical student's motivation towards career choice. Br Dent J 2002;193:471-3. [CrossRef]
24. Kuusela S, Honkala E, Hausen H, Rwakatema D, Gyua I, Lampiranta M. Opinions of dental students in Dar es Salaam (Tanzania) and in Kuopio (Finland) concerning studies and expectations for future career. Afr Dent J 1993;7:20-6.
25. Cordes DW, Doherty N, Lopez R. Assessing the economic return of specializing in orthodontics or oral and maxillofacial surgery. J Am Dent Assoc 2001;132:1679-84; quiz 725-6. [CrossRef]
26. Gallagher JE, Clarke W, Eaton KA, Wilson NH. Dentistry - a professional contained career in healthcare. A qualitative study of Vocational Dental Practitioners' professional expectations. BMC Oral Health 2007;7:16. [CrossRef]

eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2022; 56(2): 96-101

Original research

Comparison of skeletal and dentoalveolar effects of two different mandibular advancement methods: Conventional technique vs aesthetic approach

Hasan Camcı[1], **Farhad Salmanpour**[1]

Purpose
The aim of this study was to compare the effects of two different mandibular advancement methods on skeletal, dentoalveolar, and soft tissue structures through cephalometric measurements.

Materials and Methods
Twenty-four Class II division 1 patients (10 males, 14 female) treated with twin block (TB) or aesthetic approach (EA: Essix plates + Class II elastics) from the archive of our faculty were included in the study. There were 12 individuals in the EA group (mean age: 12.2 ± 1.0) and 12 individuals in the TB group (mean age: 11.8 ± 1.1 years). The skeletal, dentoalveolar, and soft tissue effects of the appliances were evaluated by performing 28 measurements, 14 linear and 14 angular, on the pre and post-treatment cephalometric radiographs. AudaxCeph 5.0 software (Ljubljana, Slovenia) was used for the analysis. A paired sample t-test was employed to assess the changes after one year of utilizing the appliance for each group. Intergroup comparison was performed by using student t test.

Results
The mandibular base was observed to move forward significantly in both groups ($p<0.05$). However, the forward movement of the mandibular base was greater in the TB group than in the EA group ($p<0.05$). There was no difference in lower incisor protrusion between the two treatment methods. The EA device was found to cause a significant increase in vertical direction parameters ($p<0.05$).

Conclusion
Both methods resulted in Class II malocclusion correction as well as an acceptable occlusion plus profile. The effects of EA were primarily dentoalveolar. In patients with high aesthetic expectations, EA could be an alternative for TB.

Keywords: *Class II malocclusion, mandibular retrognathia, mandibular advancement, twin-block, clear aligners*

Introduction

Class II division 1 malocclusion is a common anomaly in various populations (1,2). This skeletal problem is usually caused by a small or retrusive mandible (3). In growing patients, functional orthopedic devices such as monoblock or twin-block are used to treat mandibular retrognathia. These devices provide muscle activation by moving the mandible forward. The concept of stimulating bone growth via muscle activation is known as functional matrix theory (4,5). It is still debatable whether functional appliances increase mandibular growth or not (6). Some authors have suggested that these devices promote mandibular growth, while others reported that they have no effect on total mandibular length (7,8). However, there is widespread agreement that functional orthopedic devices cause upper incisor retrusion and lower incisor protrusion (9–11).

ORCID IDs of the authors: H.C. 0000-0003-0824-4192; F.S. 0000-0003-1006-9792

[1]*Department of Orthodontics, Afyonkarahisar Health Science University, Afyonkarahisar, Turkiye*

Corresponding Author: Hasan Camcı

E-mail: dt.hasan@hotmail.com

Received: 20 May 2021
Revised: 18 September 2021
Accepted: 12 November 2021

DOI: 10.26650/eor.2022939871

How to cite: *Camcı H, Salmanpour F. Comparison of skeletal and dentoalveolar effects of two different mandibular advancement methods: Conventional technique vs aesthetic approach. Eur Oral Res 2022; 56(2): 96-101. DOI: 10.26650/eor.2022939871*

The twin-block is a device that is frequently used by orthodontists to correct retrusive mandible (12). This is because a twin-block can provide both mandibular advancement and maxillary expansion simultaneously. Furthermore, allowing the patient to speak is the most important reason why this appliance is preferred. However, its bulky structure may reduce patient compliance. Accordingly, some researchers have designed new appliances to overcome the twin-blocks disadvantage. Tripathi *et al.* (13), for example, created an "esthetic twin-block" fabricated on biocryl sheet to improve patient compliance. This new design device was visually pleasing, but still bulky. The Invisalign company's mandibular advancement appliance is another option for correcting mandibular retrognathia. This appliance treats class II malocclusion by moving the mandible forward with the help of the upper and lower precision wings (14). However, this appliance is relatively bulky, and the major drawback of this device is its high cost. As a result, the authors of this study designed an easy-to-use, esthetically pleasing, and low-cost appliance for patients. The appliance is comprised of three major components: lower and upper Essix plates, plus class II elastics. The goal of this approach was to reduce the bulkiness in conventional appliances, lower the cost, and increase patient compliance.

The purpose of this study is to compare the skeletal, dentoalveolar, and soft tissue effects of the novel aesthetic approach (EA) and twin block using cephalometric analysis. The null hypothesis of the study suggested that there is no difference between the skeletal and dentoalveolar effects of the two mandibular advancement methods.

Materials and methods

Ethical statement

The research protocol of this retrospective study was approved by Afyonkarahisar Health Sciences University Clinical Research Ethics Committee (ID: 2021/89). The study was conducted in the orthodontics department of our faculty using pre- and post-treatment cephalometric radiographs of class II growing patients who underwent mandibular advancement with two different methods (EA and TB). Written informed consent forms were obtained from parents or legal guardians of the patients.

Sample size estimation

The power analysis, performed via the GPOWER software, revealed that each group required at least 11 patients (n>11, α=0.05, and 1-β=0.90) (13,15). There were twelve patients in the EA group (mean age 12.2±1.0) and twelve patients in the TB group (mean age 11.8±1.1). The following criteria were used to determine inclusion: MP3cap skeletal maturation phase, 4.5 mm overjet minimum, retrognathic mandible, optimal mandibular plane angle, ANB angles greater than 4°, and good patient compliance. Patients with a history of orthodontic treatment, anterior open bite, severe proclination of the maxillary incisors, and systemic disease affecting growth or low-quality radiographs were excluded. Except for one case in the EA group, none of the cases had an initial unilateral or bilateral crossbite. In both groups, slow expansion screws (Leone, Italy) were activated ¼ turn in 4 days to correct maxillary transversal deficiency developing following mandibular advancement. The mean number of screw activations was 31.2±2.0 in the TB group and 28.0±1.5 in the EA group.

Twinblock design

In our department, TB is routinely made in a standard design by the same technician (Figure 1). The upper removable part includes slow expansion screw, labial bow, delta, and Adam's clasps, while the lower removable part includes labial bow and Adam's clasps. In addition, one-third of the vestibular surface of the lower incisors is covered with acrylic. TB was used for a total of one year, the first six months for the entire day (except meals), and the second six months only at night.

Figure 1. *The design of twin-block.*

Mandibular advancement with Essix plates

The EA appliance fabrication process involved the following steps (Figure 2): To improve the retention of the upper part, composite attachments were placed on the right and left premolars. Upper and lower arch impressions were taken from

Figure 2. *The EA appliance design. A: frontal view, B: right lateral view, C: left lateral view, D: upper occlusal view, E: lower occlusal view.*

each patient using alginate. Plaster models were obtained. Using a vacuum machine, 0.80-inch Essix plates (Dentsply Sirona, USA) were formed. Vacuum-formed appliances were trimmed at the level of the cervical line. Metal tubes were bonded to the lower first molars with clear buttons placed on the upper canines. Class II elastics (150-200 gr per side) were used for one year, the first six months for the entire day (except meals), and the second six months only at night.

Cephalometric analysis

All measurements were performed by a single researcher using AudaxCeph version 5 software (Ljubljana, Slovenia). The analysis consisted of parameters evaluating skeletal, dental, and soft tissue changes. The parameters were selected from McNamara, Ricketts, Steiner, and Pancherz analyses (13,16–18). On the cephalometric radiographs, twenty-four anatomical landmarks were identified (Figure 3). For each patient, a total of 28 parameters were measured, including 10 skeletal, 13 dental, and 5 soft tissue.

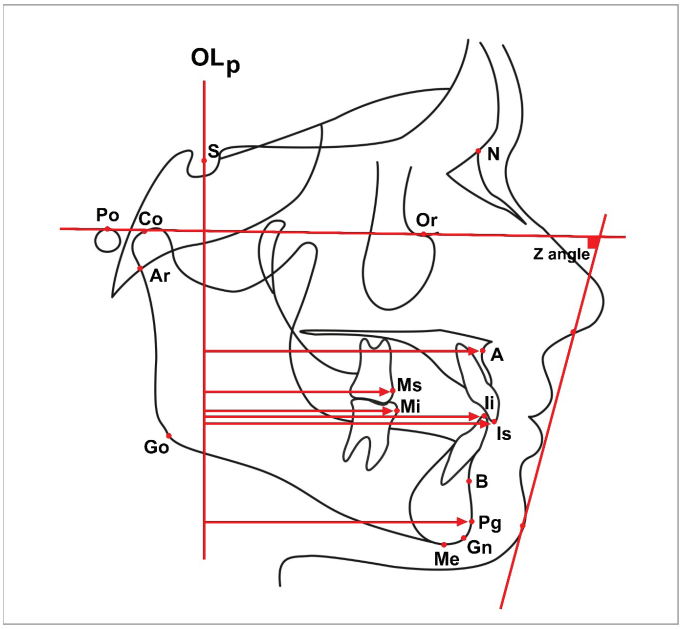


Figure 3. *S: sella, N: Nasion, Co:condylion, Ar:articulare, A: A point, B: B point, Ms: molar superior, Mi: molar inferior, Is: incisor superior, Pg: pgonion, Gn: gnathion, Me: menton, Go: gonion, Ar: articulare, Co: condylion, Po: porion, Or: orbitale, A/OLp: linear position of the maxillary base, Pg/OLp: linear position of the mandibular base, Is/OLp: position of the maxillary central incisor; Ii/OLp: position of the mandibular central, Mi/OLp: position of the lower first molar, Ms/OLp: position of the upper first molar.*

Statistical analysis

All statistical analyses were carried out using SPSS 22.0 package program (SPSS Inc, Chicago, III). Descriptive statistics such as mean values and standard deviations were calculated. The Shapiro Wilk normality test was used to determine the normality of parameters. The Student t-test was employed to compare the pre- and post-treatment results of the two groups. Skeletal, dental, and soft tissue changes that occurred after the use of TB and EA appliances were evaluated with paired sample t-test. The measurements of five randomly selected patients were reperformed two weeks later by the same researcher. The intracorrelation coefficient was calculated for each repeated measurement (Table 1). A p value <.05 was considered statistically significant.

Results

The results of skeletal, dental, and soft tissue effects of the appliances are reported in Table 1. The intracorrelation coefficient of all parameters was acceptable (Table 1). Post-treatment findings for the EA group revealed significant changes in maxillary base retraction, mandibular base advancement, increment gonial angle, upper incisors retrusion, overjet reduction, mesial movement of the lower molar, as well as retrusion of the lower and upper lip ($p<0.05$).

Post-treatment findings for the TB group revealed significant changes in mandibular base advancement, overjet reduction, mesial movement of the lower molar, upper lip protrusion, labiomental angle increment, and lower incisors protrusion ($p<0.05$).

Intergroup comparison showed that the extent of mandibular base advancement, as well as increase in nasolabial and labiomental angles was significantly higher in the TB group ($p<0.05$). More retrusion in the maxillary base and significant increase in the gonial angle were observed in the EA group ($p<0.05$). There was no significant difference between the two methods in terms of lower incisor protrusion ($p> 0.05$). A high intracorrelation coefficient was found in repeated measurements in the intra-examiner variability assessment.

Discussion

While patients today desire a beautiful smile or profile at the end of treatment, they do not want to compromise on aesthetics during the procedure. This circumstance has prompted orthodontists to develop novel appliance designs that can be used as an alternative to traditional methods (13,19). The priority in these new appliances is aesthetic appearance and ease of use.

The main issue with functional orthopedic devices, however, is patient compliance. This is because traditional mandibular advancement appliances used by class II division 1 patients are bulky and cause speech difficulties. Many patients hardly tolerate these devices, resulting in a failure rate of nearly 34% (20). The EA appliance was designed to eliminate these drawbacks and increase patient compliance. The aim of this study was to compare the effects of TB and EA appliances on skeletal, dental, and soft tissue.

There are many different points of view in the literature about when to start treatment for class II division 1 patients (21). Treatment in the pre-adolescent period is effective, but it often necessitates a longer retention period. Many studies have found that these devices are more effective in children entering their adolescent growth spurt (22). Thus, only patients in the MP3cap period were included in our study. However, some authors suggest that the effect of early treatment is no different than that of a single course of treatment performed during adolescence (23–25).

According to Clark, a twin block is an appliance designed for 24-hour wear (26). He claims that use of the appliance

Table 1: *Comparison of skeletal, dental, and soft tissue changes.*

Parameters	ICC	Treatment changes						
		Group 1 (T0-T1) N=12 EA			Group 2 (T0-T1) N=12 TB			Group 1 vs Group 2
		Mean±SD (T0)	Mean±SD (T1)	p	Mean±SD (T0)	Mean±SD (T1)	p	p
SNA (º)	0.948	83.40±3.94	82.38±4.19	0.019*	78.68±3.76	78.45±4.61	0.631	0.045*
SNB (º)	0.973	77.10±3.26	77.74±3.64	0.018*	72.12±2.97	73.88±3.62	0.000*	0.019*
ANB (º)	0.913	6.30±1.80	4.62±2.15	0.000*	6.55±1.40	4.58±1.82	0.000*	0.958
A/OLp (mm)	0.874	65.98±2.70	67.48±3.29	0.117	66.61±4.43	65.04±5.10	0.220	0.193
Pg/OLp (mm)	0.826	54.58±4.45	58.97±8.54	0.438	54.95±8.02	52.62±6.54	0.117	0.062
N-A-Pg (º)	0.798	5.11±1.50	4.05±2.48	0.075	5.88±1.83	4.04±2.26	0.000*	0.990
SN/GoGn (º)	0.776	28.53±5.02	29.63±4.85	0.003*	35.39±6.57	35.41±6.44	0.956	0.025*
N-S-Ar (º)	0.868	125.80±4.84	124.63±6.81	0.313	127.87±6.22	128.05±5.62	0.849	0.203
Co-A (mm)	0.809	84.51±4.02	84.06±4.71	0.608	83.47±3.26	83.44±4.51	0.958	0.750
Co-Gn (mm)	0.778	104.02±4.05	106.41±6.54	0.092	101.12±3.44	105.10±4.12	0.000*	0.568
L1-NB (mm)	0.932	6.06±2.17	5.40±3.20	0.633	5.46±1.58	7.10±1.53	0.000*	0.458
L1-NB (º)	0.783	28.96±6.12	30.34±8.37	0.632	26.76±6.53	32.22±5.40	0.000*	0.114
IMPA (º)	0.933	102.93±10.80	103.29±6.33	0.899	99.24±6.18	102.90±7.0	0.015*	0.526
1-NA (mm)	0.956	5.97±1.71	5.50±2.28	0.145	5.94±2.19	5.41±1.74	0.238	0.922
1/NA (º)	0.950	24.33±4.92	21.20±4.78	0.007*	24.57±7.75	23.48±4.97	0.445	0.275
U1/SN (º)	0.888	107.74±2.95	103.60±3.52	0.003*	103.25±7.48	101.95±6.60	0.371	0.460
U1/L1 (º)	0.895	120.41±7.17	123.82±10.39	0.241	122.10±10.28	119.69±7.50	0.267	0.283
Overjet (mm)	0.944	6.84±1.70	3.38±1.27	0.000*	7.63±1.97	2.94±1.04	0.000*	0.373
Molar relation (mm)	0.871	1.58±2.60	-2.79±1.89	0.000*	2.50±1.17	-1.43±1.49	0.000*	0.069
Is/OLp (mm)	0.779	69.30±4.01	70.00±5.24	0.685	70.30±7.86	65.90±5.43	0.091	0.080
Ii/OLp (mm)	0.867	62.46±4.31	66.60±5.61	0.033*	62.66±7.55	62.96±5.30	0.890	0.125
Mi/OLp (mm)	0.839	37.05±4.94	42.33±5.49	0.023*	37.11±5.54	38.35±4.83	0.562	0.079
Ms/OLp (mm)	0.799	38.60±4.24	39.55±5.67	0.584	39.64.±5.31	36.92±4.23	0.140	0.219
Upper lip to E line (mm)	0.891	0.02±1.93	-1.91±1.86	0.002*	-0.12±2.10	-2.74±1.77	0.001*	0.290
Lower lip to E line (mm)	0.765	1.68±2.29	0.30±2.07	0.044*	0.49±3.16	0.53±2.43	0.927	0.808
Nasolabial angle	0.903	109.99±7.02	108.68±8.10	0.635	102.17±6.96	101.35±7.49	0.753	0.035*
Labiomental angle	0.912	101.63±25.45	116.88±17.95	0.013*	115.72±26.20	133.01±11.07	0.023*	0.016*
Z angle	0.879	73.50±4.13	74.68±3.82	0.097	69.97±4.34	71.16±3.36	0.345	0.652

** Statistically significant changes (p<0.05), SD: Standard deviation, ICC: Intraclass correlation coefficient. Linear and angular cephalometric points measured: SNA, sella–nasion–point A angle; SNB, sella–nasion–point B angle; ANB, point A–nasion–point B angle; A/OLp, linear position of the maxillary base; Pg/OLp, linear position of the mandibular base; N-A-Pg , angle between points of nasion, A, and pogonion; SN/GoGn, the angle between Sella-nasion and gonion-gnathion planes; Co–A, maxillary length; Co–Gn, mandibular real length; L1-NB, lower incisor-nasion/point B line (mm and angle); IMPA, angle between lower incisor long axis and mandibular plane. 1/NA, upper incisor–nasion/point A line (angle and mm); U1/SN, angle between upper incisor long axis and sella-nasion plane; U1/L1, interincisal angle; Is/OLp, position of the maxillary central incisor; Ii/OLp, position of the mandibular central; Mi/OLp, position of the lower first molar; Ms/OLp, position of the upper first molar; Z angle, porion point/orbital point (Frankfort plane)–line E (Ricketts line profile) angle.*

part-time rather than full-time increases the probability of treatment failure. Class II elastics, on the other hand, should be worn for an average of 16 hours per day (27). In the current study, patients in both groups were instructed to wear the appliances full-time (except meals). As a result, device usage time was not allowed to influence the results. The forces produced by fixed functional appliances range between 150 and 200 g for each side (28). In the current study, participants in the EA group were subjected to a total force of 300-400 grams, which is similar to the value of fixed functional devices. Significant mandibular base advancement was observed in both applications. However, mandibular base advancement was greater in the TB group (Pg / OLp: 4.39 ± 8.48 mm) than in the EA group (2.32 ± 10.0). In a systematic review, Janson *et al.* (29) reported that class II elastics were effective in correcting class II malocclusion, but the treatment effects were primarily dentoalveolar. In the present study, similar results were found. Significant lower incisor protrusion was observed in the TB group (IMPA: 3.66 ± 4.39), but there was no significant lower incisor protrusion (0.35 ± 9.04) in the EA group. Concerning lower incisor protrusion, nevertheless, there was no statistically significant

difference between the two methods. Giangotti *et al.* (30) also reported minimal incisor protrusion in A-P correction using Essix plates and class II elastics. As the plates cover all teeth, this could be related to the strengthening of the anchorage of the lower incisors (31). Significant retroclination of upper incisors was observed in the EA group, which could be attributed to a reduction in rigidity caused by the appliance being separated by an expansion screw. Upper incisor palatal tipping, on the other hand, is usually a desirable outcome in class II division 1 patients.

Lower molar tooth extrusion is one of the most common side effects of using long class II elastics (32). The use of twin-block causes significant intrusion in the lower molars (33). The increase in vertical dimension angles was greater in the EA group (SN / GoGn: 1.10±0.94) than in the TB group (0.02±1.52) (p=0.025). When the EA device is used in high angle cases, short class II elastics may be preferred or the elastics can be attached from the upper lateral to the lower second molar.

When the mandible was forced forward by the functional appliances, a reciprocal force was exerted distally on the maxilla, diverting growth (34). While the SNA angle in the EA group decreased (p=0.019), there was no statistically significant difference (p=0.631) in the TB group. These findings concur with some studies but contradict others (20,35,36).

The changes in soft tissue caused by the two appliances were relatively similar. However, improvement in the labiomental sulcus was greater in the TB group (p=0.023). This was a reasonable result as the TB group had a greater forward movement of the mandibular base.

The bulky structure of the TB appliance was eliminated thanks to the EA device design. Speech problems caused by the TB appliance were clinically observed to disappear when the EA was used. Other advantages of EA included its ease of use, lack of a long and complex laboratory process, and low cost. However, the TB was clearly more durable than the EA appliance. Similarly, Saleh *et al.* (37) reported that vacuum-formed retainers are more acceptable in terms of appearance, self-confidence, and comfort.

The limitations of this study included a small sample size and undertaking it retrospectively. Another limitation of the study was the lack of a survey to assess ease of use and aesthetic expectations. Further studies are required to corroborate the present findings related to the EA approach.

Conclusion

Class II malocclusion was corrected using the EA device. A good occlusion and acceptable profile were achieved. The use of the TB appliance resulted in greater mandibular base advancement. There was no statistically significant difference in the amount of lower incisor protrusion caused by either application. In patients with high aesthetic expectations, EA may be preferred over TB. Note that use of the EA in high angle cases could be risky.

Türkçe Özet: *İki farklı mandibular ilerletme yönteminin iskelet ve dentoalveolar etkilerinin karşılaştırılması: Geleneksel yöntem ve estetik yaklaşım. Amaç: Bu çalışmanın amacı iki farklı mandibular ilerletme yönteminin iskeleletsel, dentoalveolar ve yumuşak doku etkilerinin sefalometrik röntgen ölçümleriyle karşılaştırılmasıdır. Gereç ve Yöntem: Çalışmaya fakültemiz arşivinden twin-block (TB) veya estetik yaklaşımla (EY: Essix plaklar+sınıf II elastikler) tedavi edilen yirmi dört Sınıf 2 bölüm 1 hasta (10 erkek, 14 kız) dahil edilmiştir. EY grubuna 12 birey (ortalama yaş: 12.2±1.0) ve TB grubuna (ortalama yaş: 11.8±1.1) 12 yer almaktaydı. Tedavi öncesi ve sonrası sefalometrik röntgenler üzerinde 14 linear, 14 angular olmak üzere toplam 28 ölçüm yapılarak apareylerin iskeletsel, dentaoalveolar ve yumuşak doku etkileri değerlendirildi. Analizlerde AudaxCeph 5.0 yazılımı (Ljubljana, Slovenya) kullanıldı. Bir yıllık aygıt kullanımı sonucunda ortaya çıkan değişiklikler her bir grup için bağımlı örneklem t testi ile değerlendirildi. İki yöntemin etkilerinin karşılaştırılmasında ise student t-testi kullanıldı. Bulgular: Her iki yöntemde de mandibular kaidenin belirgin olarak öne hareket ettiği gözlendi (p<0.05). Ancak TB grubunda mandibulanın öne doğru hareketi EY grubundan daha fazlaydı (p<0.05). Alt keser protrüzyonu açısından iki yöntem arasında fark yoktu. EY aygıtının vertikal yön parametrelerinde belirgin artışa neden olduğu gözlendi (p<0.05). Sonuç: Her iki yöntem ile de Sınıf II maloklüzyon düzeltilerek kabul edilebilir bir oklüzyon ve profil elde edilmektedir. EY ile ortaya çıkan düzeltme daha çok dentoalveolardir. Ancak estetik beklentileri yüksek hastalarda TB'ye alternatif olarak EY tercih edilebilir. Anahtar Kelimeler: Sınıf II maloklüzyon, Mandibular retrognati, Mandibular ilerletme, Twin-block, Şeffaf Plaklar*

Ethics Committee Approval: The research protocol of this retrospective study was approved by Afyonkarahisar Health Sciences University Clinical Research Ethics Committee. (ID: 2021/89).

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: HC participated in designing the study. HC, FS participated in generating the data for the study. HC, FS participated in gathering the data for the study. HC participated in the analysis of the data. HC wrote the majority of the original draft of the paper. HC participated in writing the paper. HC, FS have had access to all of the raw data of the study. HC, FS have reviewed the pertinent raw data on which the results and conclusions of this study are based. HC, FS have approved the final version of this paper. HC guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they hace received no conflict of interest.

References

1. Bilgic F, Gelgor IE, Celebi AA. Malocclusion prevalence and orthodontic treatment need in central Anatolian adolescents compared to European and other nations' adolescents. Dental Press J Orthod 2015;20:75–81. [CrossRef]
2. Alhammadi MS, Halboub E, Fayed MS, Labib A, El-Saaidi C. Global distribution of malocclusion traits: A systematic review. Dental Press J Orthod 2018;23:1–10. [CrossRef]
3. McNamara JA. Components of class II malocclusion in children 8-10 years of age. Angle Orthod 198;51:177–202.
4. Moss ML. The functional matrix hypothesis revisited. 4. The epigenetic antithesis and the resolving synthesis. Am J Orthod Dentofacial Orthop 1997;112:410–7. [CrossRef]
5. Moss ML. The differential roles of periosteal and capsular functional matrices in orofacial growth. Eur J Orthod 2007;29:96–101. [CrossRef]
6. Camcı H, Doruk C, Saraydin SÜ. Effect of strontium ranelate on condylar growth during mandibular advancement in rats. Turkish J Orthod 2020;33:216-23. [CrossRef]
7. Mamandras AH, Allen LP. Mandibular response to orthodontic treatment with the Bionator appliance. Am J Orthod Dentofac Orthop 1990;97:113–20. [CrossRef]
8. Vargervik K, Harvold EP. Response to activator treatment in Class II malocclusions. Am J Orthod 1985;88:242–51. [CrossRef]

9. Türkkahraman H, Sayın MÖ. Effects of activator and activator headgear treatment: comparison with untreated Class II subjects. Eur J Orthod 2006;28:27–34. [CrossRef]
10. Zelderloo A, Cadenas de Llano-Pérula M, Verdonck A, Fieuws S, Willems G. Cephalometric appraisal of Class II treatment effects after functional and fixed appliances: a retrospective study. Eur J Orthod 2016;39:334-41. [CrossRef]
11. Chen Z, Chen Q, Fan X, Li Y, Mo S. Stepwise versus single-step mandibular advancement with functional appliance in treating class II patients. J Orofac Orthop / Fortschritte der Kieferorthopädie 2020;81:311–27. [CrossRef]
12. Jena AK, Duggal R, Parkash H. Skeletal and dentoalveolar effects of Twin-block and bionator appliances in the treatment of Class II malocclusion: A comparative study. Am J Orthod Dentofac Orthop 2006;130:594–602. [CrossRef]
13. Tripathi T, Singh N, Rai P, Gupta P. Comparison of dentoskeletal changes, esthetic, and functional efficacy of conventional and novel esthetic twin block appliances among class II growing patients: A pilot study. Turkish J Orthod 2020;33:77–84. [CrossRef]
14. Al-Jewair T, Kurtzner K, Giangreco T, Warunek S, Lagravère-Vich M. Effects of clear aligner therapy for Class II malocclusion on upper airway morphology and daytime sleepiness in adults: A case series. Int Orthod 2020;18:154–64. [CrossRef]
15. Tümer N, Gültan AS. Comparison of the effects of monoblock and twin-block appliances on the skeletal and dentoalveolar structures. Am J Orthod Dentofacial Orthop 1999;116:460–68. [CrossRef]
16. McNamara JA. A method of cephalometric evaluation. Am J Orthod 1984;86:449–469. [CrossRef]
17. Ricketts RM. Perspectives in the clinical application of cephalometrics. The first fifty years. Angle Orthod 1981;51:115–50.
18. Steiner CC. Cephalometrics for you and me. Am J Orthod. 1953;39:729–55. [CrossRef]
19. Livas C. The Hybrid Aesthetic Functional (HAF) Appliance: A Less Visible Proposal for Functional Orthodontics. Case Rep Dent 2013;2013:1–7. [CrossRef]
20. O'Brien K, Wright J, Conboy F, Sanjie YW, Mandall N, Chadwick S, et al. Effectiveness of early orthodontic treatment with the Twin-block appliance: A multicenter, randomized, controlled trial. Part 1: Dental and skeletal effects. Am J Orthod Dentofac Orthop 2003;124:234–43. [CrossRef]
21. Dibiase AT, Cobourne MT, Lee RT. The use of functional appliances in contemporary orthodontic practice. Br Dent J 2015;218:123–8. [CrossRef]
22. Baccetti T, Franchi L, Toth LR, McNamara JA. Treatment timing for Twin-block therapy. Am J Orthod Dentofac Orthop. 2000;118:159–70. [CrossRef]
23. Kilpeläinen P V, Phillips C, Tulloch JF. Anterior tooth position and motivation for early treatment. Angle Orthod 1993;63:171–4.
24. Dolce C, McGorray SP, Brazeau L, King GJ, Wheeler TT. Timing of Class II treatment: Skeletal changes comparing 1-phase and 2-phase treatment. Am J Orthod Dentofac Orthop 2007;132:481–9. [CrossRef]
25. O'Brien K, Wright J, Conboy F, Appelbe P, Davies L, Connolly I, et al. Early treatment for Class II Division 1 malocclusion with the Twin-block appliance: A multi-center, randomized, controlled trial. Am J Orthod Dentofac Orthop 2009;135:573–9. [CrossRef]
26. Clark WJ. Twin Blocks designed for 24-hour wear. Am J Orthod Dentofac Orthop 2019;156:295. [CrossRef]
27. Cabrera M de C, Cabrera CAG, Freitas KMS de, Freitas MR de, Janson G, Cabrera L de C. Cephalometric effects of the use of 10-hour Force Theory for Class II treatment. Dental Press J Orthod 2012;17:31–40. [CrossRef]
28. Panigrahi P, Vineeth V. Biomechanical Effects of Fixed Functional Appliance on Craniofacial Structures. Angle Orthod 2009;79:668–75. [CrossRef]
29. Janson G, Sathler R, Fernandes TM, Branco NC, Freitas MR. Correction of Class II malocclusion with Class II elastics: a systematic review. Am J Orthod Dentofacial Orthop 2013;143:383-92. [CrossRef]
30. Giancotti A, Pirelii P, Mampieri G. Correction of Class II Malocclusions in Growing Patients by Using the Invisalign® Technique: Rational Bases and Treatment Staging. J Orthod Endod 2017;3:1-12. [CrossRef]
31. Demir A, Babacan H, Nalcaci R, Topcuoglu T. Comparison of retention characteristics of Essix and Hawley retainers. Korean J Orthod 2012;42:255–62. [CrossRef]
32. Uzel A, Uzel I, Toroglu MS. Two different applications of class II elastics with nonextraction segmental techniques. Angle Orthod 2007;77:694–700. [CrossRef]
33. Jena AK, Duggal R. Treatment effects of twin-block and mandibular protraction appliance-IV in the correction of class II malocclusion. Angle Orthod 2010;80:485–91. [CrossRef]
34. Hotz RP. Application and appliance manipulation of functional forces. Am J Orthod 1970;58:459–78. [CrossRef]
35. Illing HM, Morris DO, Lee RT. A prospective evaluation of Bass, Bionator and Twin Block appliances. Part I--The hard tissues. Eur J Orthod 1998;20:501-16. [CrossRef]
36. Trenouth MJ. Proportional changes in cephalometric distances during Twin Block appliance therapy. Eur J Orthod 2002;24:485-91. [CrossRef]
37. Saleh M, Hajeer MY, Muessig D. Acceptability comparison between Hawley retainers and vacuum-formed retainers in orthodontic adult patients: a single-centre, randomized controlled trial. Eur J Orthod 2017;39:453–61. [CrossRef]

eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2022; 56(2): 102-109

Original research

Comparison of postoperative pain after the use of different nickel-titanium instrumentation systems: A randomized clinical trial

Özlem S. Yilmaz[1], Cangül Keskin[2], Duygu H. Acar[3], Hikmet Aydemir[2]

Purpose
Postoperative pain is a common complication in endodontics contributed by multiple etiological factors, which consist canal preparation instruments and kinematics. The aim of this randomized clinical trial compare the postoperative pain in terms of intensity and incidence after the use of different nickel titanium (NiTi) file systems.

Patients and Methods
In this randomized clinical trial (NCT03791762), a total of 150 patients were root canal treated by 2 experienced endodontists according to a standardised protocol. The subjects were randomly assigned to 1 of the 3 groups according to preparation instrument used: ProTaper Next (Dentsply Sirona, Ballaigues, Switzerland), Reciproc Blue (VDW, Munich, Germany) and WaveOne Gold (Dentsply Sirona). Following preparation the teeth underwent standardized root canal treatment procedures in a single visit. The patients were contacted to gather information about the incidence of pain and intensity at 6th, 12th, 18th, 24th, 48th, and 72nd hours postoperatively. The data were analysed using chi-square, one-way analysis of variance and post hoc Tukey tests and logistic regression analysis with 5% significance threshold.

Results
No significant difference was found among preparation groups in relation to the intensity of postoperative pain. The incidence of postoperative pain was significantly linked with the preoperative pain presence with odds ratio values ranging between 2.06 and 4.08 irrespective of the preparation technique ($P<0.05$).

Conclusion
The effects of reciprocating and the continuous rotary systems on the intensity and incidence of postoperative pain were found to be similar.

Keywords: *Endodontic treatment, WaveOne Gold, postoperative pain, ProTaper Next, Reciproc Blue*

Introduction

Postoperative pain after endodontic treatment is an undesirable condition that leads to distress for both the clinician and the patient (1). Frequency of postoperative endodontic pain is common, with a reported frequency ranging between 25% and 40% (2). Postoperative pain, which is a complex and multifactorial process, may develop even following an ideal root canal treatment (3). Several etiologic factors are considered as predictive factors, including pulpal and periradicular status, sinus tracts, systemic steroid therapy, preoperative swelling, the presence and incidence of preoperative pain (4, 5). When encountered with these predictive factors, clinicians take preoperative and perioperative measures to manage postoperative pain. These management strategies may include pre and postoperative use of pharma-

ORCID IDs of the authors: Ö.S.Y. 0000-0002-5669-8343; C.K. 0000-0001-8990-4847; D.H.A. 0000-0003-4405-1777; H.A. 0000-0001-5750-8831

[1]Department of Endodontics, Faculty of Dentistry, Karabuk University, Karabuk, Turkiye

[2]Department of Endodontics, Faculty of Dentistry, Ondokuz Mayis University, Samsun, Turkiye

[3]Private practice, Istanbul, Turkiye

Corresponding Author: Cangül Keskin

E-mail: canglkarabulut@gmail.com

Received: 12 August 2021
Revised: 21 September 2021
Accepted: 16 January 2022

DOI: 10.26650/eor.2022873271

How to cite: *Yilmaz OS, Keskin C, Acar DH, Aydemir H. Comparison of postoperative pain after the use of different nickel-titanium instrumentation systems: A randomized clinical trial. Eur Oral Res 2022; 56(2): 102-109. DOI: 10.26650/eor.2022873271*

cologic agents such as the use of antihistamines, paracetamol, non-steroidal antiinflammatory drugs (NSAI) and nonpharmacologic methods that can be used to adapt treatment procedures such as occlusial reduction, canal preparation technique, the use of intracanal medicaments (6-8). Root canal preparation is emphasized as an important factor to achieve thorough disinfection along with high volume of irrigation (7).

Standard root canal preparation has been carried out with the use of different instruments and kinematics. Rapid technological advances in the endodontic instrumentation systems introduce new design concepts with the claim of easier and faster preparations that preserve the original canal shape with considerably less iatrogenic error (9, 10). The manufacturers also claim to achieve more favorable treatment outcome with less postoperative pain rate. ProTaper Next (PTN) (Dentsply, Sirona) is a popular continous rotating instrumentation system which is manufactured from M-wire nickel-titanium (NiTi) showing enhanced flexibility and fatigue resistance over conventional NiTi (11). WaveOne Gold (WOG) (Dentsply, Sirona) is a reciprocating instrument manufactured via a special thermomechanical treatment termed as Gold treatment. WaveOne Gold instruments show novel parallelogram cross-sectional shape with 2 cutting edges, and consist of 4 instruments as 21/06 (small), 25/07 (primary), 35/06 (medium) and 45/05 (large) (12). The Reciproc Blue (RB) (VDW, Munich, Germany), another thermally treated reciprocating single-file system with a design identical to that of its predecessor, the Reciproc with the advancement of Blue wire providing increased fatigue resistance and flexibility (13, 14). These novel thermally treated systems have design modifications such as changing tapers, different cross-sections, variable helicoidal angles that have been associated with postoperative pain by affecting the amount of extruded debris (15-18).

Debris extrusion is an inevitable complication during the cleaning and shaping procedures, both with manual stainless steel and nickel-titanium rotary instrumentation techniques (15, 19). The instrument kinematics have been improved to minimize the amount of extruded debris during preparation, while conflicting findings have been reported regarding the amount of extruded debris by instruments with continuous rotation or reciprocation in the literature. Several clinical studies compared reciprocating and rotating systems and linked instrument kinematics with the postoperative pain (16, 17, 20-22). A meta-analysis concluded that preparation with rotary instrumentation was linked with a lower pain incidence compared to the preparation with reciprocating instruments in single visit cases (18). According to our literature review, the effect of root canal preparation using Reciproc Blue and WaveOne Gold on the incidence and intensity of postoperative pain has not yet been compared by a randomised controlled clinical trial. This study aimed to compare the postoperative pain after use the of PTN, RB or WOG. The null hypothesis was established as no significant difference was expected in term of the intensity and incidence of postoperative endodontic pain after root canal preparation using any of the 3 instruments.

Patients and methods

Ethical board approval and selection of participants

Study protocol was approved by local university clinical researches ethical board (KAEK/389) and also registered in ClinicalTrials.gov (NCT03791762). A priori sample size calculation was performed using a computational software (G*Power, G*Power 3.1 for Macintosh, Heinrich-Heine, Düsseldorf, Germany) F test family based on the effect size of a previous study (21). Based on a type I error of .05 and a power of 80%, a minimum sample size of 39 would be required to detect differences among groups. Fifty patients per group were included to the study due to a possible dropout rate of 10% (n = 50). Patients with systemic diseases, apical abscess or multiple teeth requiring treatment, showing signs of systemic infection, currently taking medications until 7 days prior to the procedure (analgesic, anti-inflammatory drugs, antibiotics or corticosteroids), or having a drug allergy were excluded from the study (Figure 1). Subjects were informed about the study protocol and signed informed consent forms before treatment. The study included teeth diagnosed with symptomatic/asymptomatic irreversible pulpitis or symptomatic/asymptomatic apical periodontitis. The clinical diagnosis of symptomatic irreversible pulpitis was based on positive pulp sensibility test result, presence of spontaneous pain, lingering provoked pain longer than 30 seconds, and deep caries, extensive restorations or fractures exposing the pulp. The clinical diagnosis of asymptomatic irreversible pulpitis was based on the absence of clinical symptoms and presence of a deep carious lesion that will eventually result in a large pulp exposure following removal. Symptomatic apical periodontitis was diagnosed according to the presence of painful response to biting / percussion / palpation, spontaneous pain and periradicular radiographical features varying from a normal periapical structures to a periapical radiolucency, whereas asymptomatic apical periodontitis was diagnosed according to the absence of clinical symptoms, responsiveness to pulp sensibility tests and the presence of a periapical radiolucency. Thermal and electric pulp tests were performed to determine pulp sensibility. Preoperative periapical radiographs were taken with a digital radiography system (Sirona Vario DG, Bensheim, Germany). Two independent blinded endodontists analysed clinical and radiological data sheets, which was obtained and filled for each subject. A third opinion of an endodontist was obtained when conflicts arose. Table 1 provides a summary of the baseline demographic and clinical properties of the study groups.

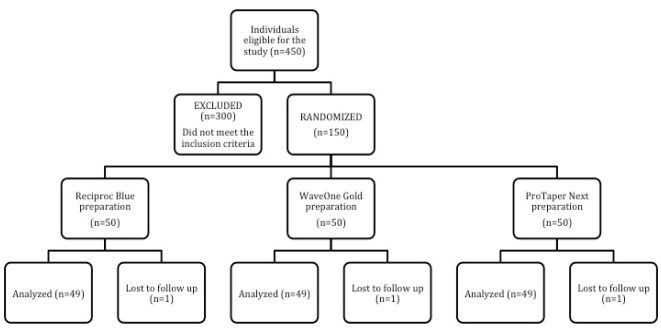


Figure 1. *Flow diagram CONSORT for randomised clinical trials.*

Table 1: *Baseline demographic and clinical features of the patients in the study groups.*

Baseline demographic and clinical features	ProTaper Next, n(%) (n=50)	Reciproc Blue, n(%) (n=50)	WaveOne Gold n(%) (n=50)	Total (n=150)
Female	26 (31.3)	27 (31.3)	31 (37.4)	84
Male	24 (36.3)	23 (34.8)	19 (28.9)	66
Vital	36 (30.7)	42 (35.89)	39 (33.4)	117
Nonvital	14 (42.4)	8 (24.2)	11 (33.4)	33
Incisor Teeth	5 (27.7)	7 (38.8)	6 (33.5)	18
Premolar Teeth	12 (31.6)	14 (36.8)	12 (31.6)	38
Molar Teeth	33 (35.1)	29 (30.8)	32 (34.1)	94
Frequency of preoperative pain	39 (78)	35 (70)	42 (84)	116

Treatment procedures

Root canal treatments were performed by 2 endodontists between June 2018 and December 2018. All treatments were completed in a single visit. The patients were trained about the use of visual analogue scale (VAS) forms. Treatment preparation included the administration of 2.0 mL local anesthesia 4% articaine with adrenaline 1:100.000, which might be followed by an additional 2.0 mL carpule of 4% articaine use when necessary. Before treatment 1 of the 3 sealed envelope, which was written the experimental group name was selected by a third person, who was not involved in the study and kept sealed until root canal preparation phase. Traditional endodontic access cavities were prepared. Glide path was created with stainless steel #8, 10, 15 K-files with push and pull motion at apical direction. Working length (WL) was determined using a 10 K-file and electronic apex locator (Root ZX Mini, Morita, Kyoto, Japan) and periapical radiography (Sirona Vario DG, Bensheim, Germany). Then, the envelope was opened and the subject was assigned to 1 of the 3 preparation groups according to the root canal instrumentation system as RB, WOG and PTN. All instrumentation procedures were performed according to the manufacturers' instructions. Patients did not know which experimental group they were assigned to.

Group PTN. In the ProTaper Next group, following preparation of the root canals with X1 and X2 instruments at WL, a 25 K-file was introduced to the canals. If the instrument was passively introduced to the WL, the root canals were prepared with subsequent X3 instruments. Then 30 or 40 K-files were introduced to the canals and root canals were prepared with X4 or X5 instruments when required. The instruments were operated with continuous rotary brushing motion at a speed of 300 rpm and a torque of 2 Ncm using apex locator entegrated endomotor (VDW Gold, VDW, Munich, Germany).

Group RB. In the Reciproc Blue group, instrument selection was performed based on the dimensions of root canals **(23)**. If a 30 K-file was passively introduced into the root canals up to WL, this root canal was considered as large and R50 (50.05) instrument was selected. When a 30 K-file failed to reach the WL and a 20 K-file was introduced into the WL, the root canal was considered as medium and R40 (40.06) instrument was selected. When a 20 K-file failed to reach the WL, this canal was considered as narrow and R25 (25.08) instrument was selected. Three pecking motion with 3 mm amplitude followed by removal and cleaning of th e instrument was performed until the established WL was achieved. The instruments were operated with Reciproc ALL mode of the same apex locator integrated endomotor (VDW Gold, Munich, Germany).

Group WOG. In the WaveOne Gold group, the Small file (20.07) was used to prepare the root canals if a 25 K-file failed to reach the WL. When a 25 K-file was passively introduced to the WL, the Primary file (25.07) was selected for preparation. When a 25 K-file was passively introduced to the WL, the Medium file (35.06) was selected. When a 35 K-file was passively introduced to the WL, the Large file (45.05) was selected. Three pecking motions with 3 mm amplitude followed by removal and cleaning of the instrument was performed until the established WL was achieved. The instruments were operated with WaveOne ALL mode of the same apex locator integrated endomotor (VDW Gold, Munich, Germany).

During preparation of each canal was flushed with 10 mL of 5.25% NaOCl with a 30-G needle syringe. Patency of the apical foramen was maintained during all the techniques by introducing a #10 K-type file (Dentsply Sirona) to a point 0.5 mm beyond the working at each instrument change. After preparation, final irrigation of each root canal included flushing with 5 mL of 17% EDTA, 2.5 mL distilled water and 2.5 mL of 5.25% NaOCl, respectively. Then, the canals were dried with sterile paper points. Root canal obturation was performed by cold lateral compaction technique using epoxy resin sealer (AH Plus Jet, Dentsply Sirona, Ballaigues, Switzerland) and gutta-percha. Coronal restorations were performed with composite resin filling material (Gradia Direct, GC Dental, Tokyo, Japan). After treatment, the patients were recommended to take 600 mg ibuprofen only if necessary and record their analgesic intake. Then the patients were discharged with VAS forms. No prescription was prepared for any medication. Following 3 days, the patients were contacted via telephone for the record of their postoperative 6th, 12th, 18th, 24th, 48th, and 72nd hour VAS scores.

Statistical analysis

Distribution of possible confounding factors such as gender (female/male), age, pulp sensibility (nonvital/vital), tooth type (incisor/premolar/molar), and preoperative pain (present/absent) among groups were tested with chi-square test. Distribution of postoperative VAS scores was tested for

normality and confirmed normal distribution. Prior to treatment, the patients were instructed how to complete a visual analogue scale (VAS) to determine their preoperative and postoperative pain scores. The VAS forms included a 10 cm straight horizontal line numbered at each centimetre from 0 to 10. The beginning of the line was defined as '0=no pain' and the ending was defined as'10=the most severe pain experienced'. Scores of postoperative pain intensity were analysed with by one-way analysis of variance and post-hoc Tukey tests. Then a logistic regression analysis was performed to assess the importance of the preparation group and confounding variables for the prediction of postoperative pain. Model fit was assessed with Hosmer-Lemeshow goodness of fit statistics. SPSS software (v.18.0; IBM, Chicago, IL, USA) was used to for all statistical analyses.

Results

A total of 150 patients were enrolled but one patient of each group was excluded because they could not be contacted for follow-up. None of the patients applied with the complaint of inter-appointment flare-up. Five patients in the PTN group (2 paracetamol intake for 3 patients and 1 NSAI intake for 3), one patient in the RB group (1 NSAI) and four patients in the WOG group (1 NSAI) reported analgesic intake in the first 48 hours.

The distribution of gender, age, pulp sensibility, preoperative pain severity and incidence, and tooth type were found similar among the experimental groups.

The mean VAS pain scores were shown in the Figure 2. Preoperative pain scores were similar among groups. At all postoperative measurement intervals, there were no significant differences among preparation groups regarding the postoperative VAS scores. The frequency of patients reported postoperative endodontic pain in each experimental group was presented in Table 2.

Table 3 presents the logistic regression analysis results at each time intervals. Hosmer-Lemeshow tests showed good level of fit for all time intervals. Only the presence of preoperative pain variable showed significant influence on the presence of postoperative pain during the first 24 hour (*P<0.05)*. Root canal preparation method was not a significant predictive factor at all time intervals. When the subjects had preoperative endodontic pain they tend to report more pain (*P<0.05)* with odd ratio values varied between 2.06 and 4.08 irrespective of the preparation system.

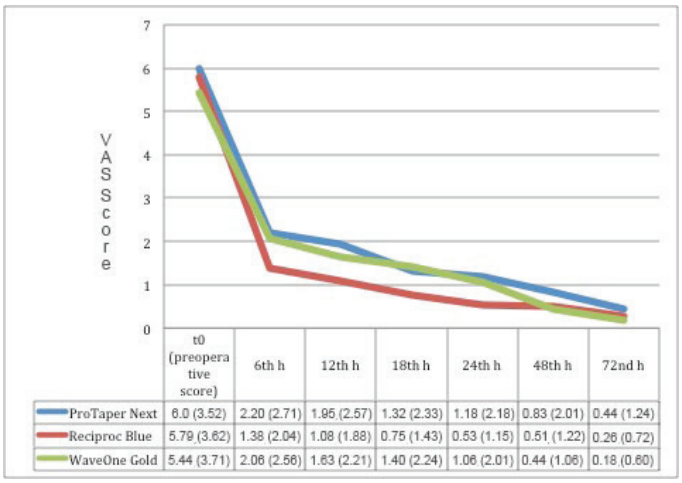


Figure 2. *Mean (standard deviation) values for preoperative and 6 postoperative VAS scores after preparation using ProTaper Next, Reciproc Blue and WaveOne Gold instruments.*

Table 2: *Number and frequency of patients who reported presence of pain following root canal treatment at measured intervals, n(%).*

	6th h	12th h	18th h	24h h	48th h	72nd h
ProTaper Next	25 (51.0)	17 (67.3)	17 (67.3)	15 (30.6)	11 (22.4)	9 (18.3)
Reciproc Blue	19 (38.7)	17 (34.6)	13 (25.5)	10 (20.4)	9 (18.3)	7 (14.2)
WaveOne Gold	27 (55.1)	23 (46.9)	19 (38.7)	15 (30.6)	9 (18.3)	5 (10.2)

Discussion

The use of reciprocating instruments was correlated with increased postoperative pain incidence compared to continuous rotation in parallel to greater amount of apically extruded debris reports (18, 22, 24, 25). However the effect of instrument kinematics on the amount of extruded debris is not evidenced in the presence of the various conflicting results caused by the use of different instruments varying with cutting efficacy, alloy type, cross-sectional shape, number of files used, pitch design and taper (22). As an attempt to standardise the instrument related factors, an in vitro study compared the debris extruded during reciprocation and continuous rotation using the same instrument and reported that the continuous rotation caused significantly greater amount of extruded debris, while another study also standardized the instrument and reported similarity between reciprocation and continuous rotation (25-27). Well designed randomized clinical trials are warranted to evaluate the effect of different instrumentation systems on postoperative pain since in vitro results may not apply to clinical situations. Therefore, the aim of this prospective clinical trial was to compare the incidence and intensity of postoperative pain after the use of different NiTi instrumentation systems. Since the results of the study revealed similarity among RB, WOG and PTN; the null hypothesis was not rejected.

Various instrumentation systems were associated with the some degree of postoperative pain (16, 20, 21, 26-28). Two clinical trials reported similarity regarding the intensity of postoperative pain between OneShape and reciprocating single file groups; WaveOne and Reciproc (29, 30). Creation of glide path with reciprocating or rotating instruments caused similar degree of postoperative pain (31). Another randomized trial reported that the use of PTN or Reciproc exerted a similar impact on quality of life (32). The results of the present study showed that no significant difference was observed in the incidence of postoperative pain after use of PTN, RB, and WOG. These results are in accordance with those clinical trials, however the compared instruments were different apart from the comparison of reciprocation and rotation motions (18, 22, 28). The differences might stem from methological differences, including subject number and randomization, the use of different irrigation agents

Table 3: *Odd ratios, 95% confidence intervals (CI) and associated p values for logistic regression models of the data of the postoperative pain incidence for each measurement intervals.*

Time interval	Variable	P value (95%CI)	Odds ratio
6th hour	**Group**		
	ProTaper (reference)	0.26	-
	Reciproc Blue	0.18 (0.76-4.2)	1.79
	WaveOne Gold	0.86 (0.39-2.17)	0.92
	Gender (female vs. male)	0.81 (0.53-2.21)	1.08
	Preoperative pain presence (absent vs. present)	0.04 (1.29-6.41)	2.29
	Vitality (nonvital vs. vital)	0.18 (0.18-1.2)	0.47
12th hour	**Group**		
	ProTaper (reference)	0.42	-
	Reciproc Blue	0.26 (0.09-3.75)	1.61
	WaveOne Gold	0.93 (0.42-2.2)	0.96
	Gender (female vs. male)	0.64 (0.42-1.7)	0.84
	Preoperative pain presence (absent vs. present)	0.04 (0.8-5.1)	2.06
	Vitality (nonvital vs. vital)	0.11 (0.2-1.26)	0.50
18th hour	**Group**		
	ProTaper (reference)	0.49	-
	Reciproc Blue	0.32 (0.63-3.9)	1.57
	WaveOne Gold	0.91 (0.4-2.2)	0.95
	Gender (female vs. male)	0.86 (0.5-2.25)	1.06
	Preoperative pain presence (absent vs. present)	0.01 (1.3-12.9)	4.08
	Vitality (nonvital vs. vital)	0.05 (0.12-1.02)	0.35
24th hour	**Group**		
	ProTaper (reference)	0.42	-
	Reciproc Blue	0.22 (0.6-4.7)	1.81
	WaveOne Gold	0.71 (0.48-2.92)	1.18
	Gender (female vs. male)	0.26 (0.7-3.52)	1.58
	Preoperative pain presence (absent vs. present)	0.03 (1.06-14.0)	3.87
	Vitality (nonvital vs. vital)	0.09 (0.11-1.18)	0.37
48th hour	**Group**		
	ProTaper (reference)	0.71	-
	Reciproc Blue	0.59 (0.47-3.68)	1.32
	WaveOne Gold	0.43 (0.54-4.18)	1.50
	Gender (female vs. male)	0.45 (0.57-3.36)	1.39
	Preoperative pain presence (absent vs. present)	0.08 (0.85-17.9)	3.90
	Vitality (nonvital vs. vital)	0.15 (0.1-1.4)	0.38
72nd hour	**Group**		
	ProTaper (reference)	0.43	-
	Reciproc Blue	0.49 (0.48-4.43)	1.47
	WaveOne Gold	0.20 (0.65-7.14)	2.16
	Gender (female vs. male)	0.70 (0.45-3.21)	1.21
	Preoperative pain presence (absent vs. present)	0.20 (0.58-12.9)	2.75
	Vitality (nonvital vs. vital)	0.83 (0.26-2.9)	0.88

with different volumes, variances in tooth types, the choice of blinding procedures, which pain scales were used, and varying follow-up durations.

In the present study, postoperative pain intensity was the highest in the early hours postoperative and then decreased substantially after 48 hours in all groups, which is congruent

with the existing literature (32, 33). The frequency of severe and moderate pain decreased by the time as the frequency of mild and no pain increased. Interestingly, WOG group, which showed the greatest incidence of postoperative pain among groups (n=27) also showed the greatest reduction from 55% to 10% from 6th hours to 72nd hours. In RB group least postoperative pain incidence was detected with 19 patients. It is also worth to mention that mean postoperative pain values at postoperative 6th hours were below 3 in all preparation groups. The persistence of mild pain might be related to the continuing inflammatory processes particularly in the presence of preexisting periradicular inflammation or injection wounds, pressure of the rubber dam clamp, or the discomfort due to prolonged mouth opening.

Kherlakian *et al.* (21) compared the postoperative pain following preparation with PTN, Reciproc and WaveOne instruments in 210 healthy teeth root canal treated for prosthetic rehabilitation and reported similarity between rotary and reciprocating systems in agreement with the present study also evaluating PTN with novel reciprocating instruments (21). However, apart from the different alloys Blue and Gold wire, the design of the RB is identical with Reciproc instruments, while WOG displays less taper and different cross-sectional shape from WaveOne. WaveOne instruments were reported to extrude greater amount of debris compared to WOG due to its greater taper and triangular cross-section that causes screwing effect pushing the debris apically (34). Increased flexibility of the thermally treated NiTi alloys have been indicated to lead a decreased amount of extruded debris (34). In the present study, no difference was detected between reciprocating and continuous rotation groups. In all subjects, glide path was created or followed, patency was achieved; irrigation solution, volume and technique were standardized and manufacturers' recommendations were strictly followed during instrumentation. Along with these factors and homogenous distribution of demographic factors and preoperative pain incidence in groups might contribute to the similarity among instrumentation techniques in terms of postoperative pain occurrence and intensity.

Apical patency has been discussed due to the potential apical extrusion of infected debris risk with the assumption that it would increase postoperative pain. Two recent meta-analyses concluded that maintanence of patency does not increase postoperative pain and analgesic intake (35, 36). Based this information, apical patency was maintained in our study.

Standardization of all possible confounding variables would clarify the actual effect of the investigated variable on the postoperative pain levels. However, given the large sample size and multifactorial nature of the endodontic pain, elimination of all confounding factors would not be possible, which constitutes a major limitation. Therefore, in the present study the homogenous distributions of subject related factors such as gender, tooth type, pulp sensibility and the preoperative pain were confirmed. The effects possible confounding factors on the incidence of postoperative pain was also analysed. Some studies have concluded that variables such as gender, age, tooth type and preoperative pain are significant factors for the development of postoperative pain (4, 37). The presence of preoperative pain emerged as a significant factor for the incidence of postoperative pain apart from patient gender, tooth type and preparation group. These findings are in accordance with the previous literature that reported that greater postoperative pain incidence is significantly linked with the presence of preoperative pain (5, 38). Today, preoperative pain is considered as a significant factor for the prediction of postoperative pain (2, 3). Therefore, patients whose chief complaint is endodontic pain could be warned about probable postoperative pain and possible need for analgesic intake.

In the present study subjective nature of the pain evaluation method could be considered as a limitation. The visual analogue scale was used to assess pain levels as it is a basic method with greater reliability, validity and sensitivity than descriptive scales (39, 40). Pain was followed up to 72 hours after the completion of root canal treatment as the incidence and intensity of pain were the greatest in the first 24 hours and then decreased substantially after 48 hours. As the follow up period of postoperative pain included the first 48 to 72 hours after treatment in several clinical studies (41, 42). Another limitation was the inability of blinding the operators regarding the groups; however, assignment of the patients to the experiment groups was performed after working length determination just prior to the root canal preparation step to minimize a possible selection bias. All patients included in the study were treated in a single visit. Therefore, the findings of the present study can not be applied or interpreted for multiple-visit treatments, which warrants for further randomized clinical trials.

Conclusion

Within the limitations of the present randomized clinical trial, Reciproc Blue, WaveOne Gold and ProTaper Next canal preparation systems had similar postoperative pain intensity and incidence following single visit root canal treatment. The presence of preoperative pain was the most significant predictive factor for the occurrence of postoperative pain.

Türkçe Özet: *Farklı Nikel-Titanyum Enstrümantasyon Sistemlerinin Kullanımı Sonrası Postoperatif Ağrının Karşılaştırılması: Randomize Klinik Çalışma. Amaç: Postoperatif ağrı, kanal preparasyonunda kullanılan aletler ve kinematiklerinin de içinde bulunduğu çok sayıda etiyolojik faktörün sebep olduğu endodontide sık görülen bir komplikasyondur. Bu randomize klinik çalışmanın amacı, farklı nikel titanyum (NiTi) eğe sistemlerinin kullanımından sonra postoperatif ağrının yoğunluğunu ve insidansını karşılaştırmaktır. Gereç ve Yöntem: Bu randomize klinik çalışmada (NCT03791762), toplam 150 hastaya standart bir protokole göre iki deneyimli endodontist tarafından kök kanal tedavisi uygulandı. Denekler, kullanılan preparasyon sistemine göre 3 gruptan birine rastgele atandı: ProTaper Next (Dentsply Sirona, Ballaigues, İsviçre), Reciproc Blue (VDW, Münih, Almanya) ve WaveOne Gold (Dentsply Sirona, İsviçre). Kanal preparasyonunun ardından dişlere tek seans standardize kanal tedavisi prosedürleri uygulandı. Hastalarla postoperatif 6., 12., 18., 24., 48. ve 72. saatlerde ağrı insidansı ve şiddeti hakkında bilgi almak için iletişime geçildi. Veriler, ki-kare, tek yönlü varyans analizi ve post hoc Tukey testleri ve% 5 anlamlılık eşiği ile lojistik regresyon analizi kullanılarak analiz edildi. Bulgular: Gruplar arasında postoperatif ağrının şiddetine göre anlamlı bir fark olmadığı tespit edildi. Postoperatif ağrı insidansı, instrumantasyon sistemlerine bakılmaksızın 2.06 ile 4.08 arasında değişen odds oranları ile preoperatif ağrı varlığı ile anlamlı ilişki gösterdi (P <.05). Sonuç: Postoperatif ağrının şiddeti ve insidansı açısından resiprokasyon yapan ve devamlı rotasyon yapan sistemler benzer bulunmuştur. Anahtar kelimeler: Endodontik tedavi; WaveOne Gold; postoperatif ağrı; ProTaper Next; Reciproc Blue*

Ethics Committee Approval: The study protocol was approved by the ınıversity ethical board (KAEK/389) and it was also registered to ClinicalTrials.gov (NCT03791762).

Informed Consent: Participants provided informed consent.

Peer-review: Externally peer-reviewed.

Author contributions: OSY, CK, HA participated in designing the study. OSY, CK, DHA participated in generating the data for the study. OSY, CK, DHA participated in gathering the data for the study. OSY, CK, DHA, HA participated in the analysis of the data. OSY, CK, DHA, HA wrote the majority of the original draft of the paper. OSY, CK, DHA, HA participated in writing the paper. OSY, CK, DHA, HA have had access to all of the raw data of the study. OSY, CK, DHA, HA have reviewed the pertinent raw data on which the results and conclusions of this study are based. OSY, CK, DHA, HA have approved the final version of this paper. OSY guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they have received no financial support.

References

1. Mohammadi Z, Shalavi S, Giardino L, Palazzi F, Asgary S. Impact of ultrasonic activation on the effectiveness of sodium hypochlorite: A review. Iran Endod J 2015;10:216-20.
2. Nixdorf D R, Moana-Filho E J, Law A S, McGuire L A, Hodges J S, John M T. Frequency of persistent tooth pain after root canal therapy: a systematic review and meta-analysis. J Endod 2010;36:224-30. [CrossRef]
3. Walton R, Fouad A. Endodontic interappointment flare-ups: a prospective study of incidence and related factors. J Endod 1992;18:172-7. [CrossRef]
4. Wang C, Xu P, Ren L, Dong G, Ye L. Comparison of post-obturation pain experience following one-visit and two-visit root canal treatment on teeth with vital pulps:a randomized controlled trial. Int Endod J 2010;43:692-7. [CrossRef]
5. Ali A, Olivieri J G, Duran-Sindreu F, Abella F, Roig M, Garcia-Font M. Influence of preoperative pain intensity on postoperative pain after root canal treatment: A prospective clinical study. J Dent 2016;45:39-42. [CrossRef]
6. Siqueira J F, Barnett F. Interappointment pain: mechanisms, diagnosis and treatment. Endod Topics 2004;7:93-109. [CrossRef]
7. De-Deus G, Belladonna F G, Souza E M, Vde O A, Silva E J, Rodrigues E, Versiani M A, Bueno C E. Scouting ability of 4 pathfinding instruments in moderately curved molar canals. *J Endod 2016;*42:1540-4. [CrossRef]
8. Blicher B, Lucier Pryles R. Endodontic pain management: preoperative, perioperative, and postoperative strategies. Compend Contin Educ Dent. 2020;41:242-3.
9. Gambarini G. The K3 rotary nickel titanium instrument system. Endod Topics 2005;10:179-82. [CrossRef]
10. Peters O A. Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004;30:559-67. [CrossRef]
11. Pereira E S J, Gomes R O, Leroy A M, Singh R, Peters O A, Bahia M G, Buono V T. Mechanical behavior of M-Wire and conventional NiTi wire used to manufacture rotary endodontic instruments. Dent Mater J 2013;29:318-24. [CrossRef]
12. Adıgüzel M, Capar I D. Comparison of cyclic fatigue resistance of WaveOne and WaveOne gold small, primary, and large instruments. J Endod 2017;43:623-7. [CrossRef]
13. Keskin C, İnan U, Demiral M, Keleş A. Cyclic fatigue resistance of Reciproc Blue, Reciproc, and WaveOne Gold reciprocating instruments. J Endod 2017;43:1360-3. [CrossRef]
14. De-Deus G, Silva E J, Vieira V T, Belladonna F G, Elias C N, Plotino G, Grande N M. Blue thermomechanical treatment optimizes fatigue resistance and flexibility of the Reciproc files. J Endod 2017;43:462-6. [CrossRef]
15. Caviedes-Bucheli, J, Moreno J O, Carreño C P, Delgado R, Garcia D J, Solano J, Diaz E, Munoz H R. The effect of single-file reciprocating systems on Substance P and Calcitonin gene-related peptide expression in human periodontal ligament. Int Endod J 2013;46:419-26. [CrossRef]
16. Gambarini, G, Testarelli L, De Luca M, Milana V, Plotino G, Grande N M, Rubini A G, Al Sudani D, Sannino G. The influence of three different instrumentation techniques on the incidence of postoperative pain after endodontic treatment. Ann Stomatol (Roma) 2013;4:152-5. [CrossRef]
17. Arslan H, Khalilov R, Doğanay E, Karatas E. The effect of various kinematics on postoperative pain after instrumentation: a prospective, randomized clinical study. J Appl Oral Sci 2016;24:503-8. [CrossRef]
18. Hou X, Su Z, Hou B. Post endodontic pain following single-visit root canal preparation with rotary vs reciprocating instruments: a meta-analysis of randomized clinical trials. BMC Oral Health 2017;17:86. [CrossRef]
19. Shokraneh A, Ajami M, Farhadi N, Hosseini M, Rohani B. Postoperative endodontic pain of three different instrumentation techniques in asymptomatic necrotic mandibular molars with periapical lesion: a prospective, randomized, double-blind clinical trial. Clin Oral Invest 2017;21:413-8. [CrossRef]
20. Neelakantan P, Sharma S. Pain after single-visit root canal treatment with two single-file systems based on different kinematics—a prospective randomized multicenter clinical study. Clin Oral Invest 2015;19:2211-7. [CrossRef]
21. Kherlakian D, Ehrhardt I C, Zuolo M L, Kishen A, da Silveira Bueno C E. Comparison of the incidence of postoperative pain after using 2 reciprocating systems and a continuous rotary system: a prospective randomized clinical trial. J Endod 2016;42:171-6. [CrossRef]
22. Burklein S, Schafer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod 2012;38:850-2. [CrossRef]
23. Yared G. Reciproc blue: the new generation of reciprocation. G Ital Endod. 2017;31:96-101. [CrossRef]
24. Topçuoğlu H S, Zan R, Akpek F, Topçuoğlu G, Ulusan Ö, Aktı A, Düzgün S, Ağırnaslıgil M. Apically extruded debris during root canal preparation using Vortex Blue, K3XF, ProTaper Next and Reciproc instruments. Int Endod J 2016;49:1183-7. [CrossRef]
25. Arslan H, Doğanay E, Alsancak M, Çapar I D, Karataş E, Gündüz H A. Comparison of apically extruded debris after root canal instrumentation using Reciproc instruments with various kinematics. Int Endod J 2016;49:307-10. [CrossRef]
26. De-Deus G, Brandao M C, Barino B, Di Giorgi K, Fidel R A, Luna A S. Assessment of apically extruded debris produced by the single-file ProTaper F2 technique under reciprocating movement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:39-4. [CrossRef]
27. Gambarini G, Di Nardo D, Miccoli G, Guerra F, Di Giorgio R, Di Giorgio G, Glassman G, Piasecki L, Testarelli L. The influence of a new clinical motion for endodontics instruments on the incidence of postoperative pain. Clin Ter 2017;168:e23-7.
28. Kashefinejad M, Harandi A, Eram S, Bijani A. Comparison of single visit post endodontic pain using mtwo rotary and hand k-file ınstruments: A randomized clinical trial. J Dent (Tehran, Iran) 2016;13:10-7.
29. Mollashahi N F, Saberi E A, Havaei S R, Sabeti M. Comparison of postoperative pain after root canal preparation with two reciprocating and rotary single-file systems: A randomized clinical trial. Iran Endod J 2017;12:15-9.
30. Jain N, Pawar A M, Naganath M, Gupta A, Daryani H. Incidence and severity of postoperative pain after canal instrumentation with reciprocating system, continuous rotary single file system, versus SAF system. Endo Pract (Lond Engl) 2016;10:153-60.

31. Keskin C, Sıvas Yılmaz O, İnan U, Özdemir Ö. Postoperative pain after glide path preparation using manual, reciprocating and continuous rotary instruments: a randomized clinical trial. Int Endod J 2019;52:579-82. [CrossRef]
32. Oliveira PS, da Costa KNB, Carvalho CN, Ferreira MC. Impact of root canal preparation performed by ProTaper Next or Reciproc on the quality of life of patients: a randomized clinical trial. Int Endod J 2019;52:139-48. [CrossRef]
33. Oguntebi B R, DeSchepper E J, Taylor T S, White C L, Pink F E. Postoperative pain incidence related to the type of emergency treatment of symptomatic pulpitis. Oral Surg Oral Med Oral Pathol 1992;73:479-83. [CrossRef]
34. Karataş E, Ersoy İ, Gündüz H A, Uygun A D, Kol E, Çakıcı F. Influence of instruments used in root canal preparation on amount of apically extruded debris. Artif Organs 2016;40:774-7. [CrossRef]
35. Yaylali IE, Demirci GK, Kurnaz S, Celik G, Kaya BU, Tunca YM. Soes maintaining apical patency during instrumentation increase postoperative pain or flare-up rate after nonsurgical root canal treatment? A systematic review of randomized controlled trials. J Endod 2018;44:1228-36. [CrossRef]
36. Abdulrab S, Rodrigues JC, Al-Maweri SA, Halboub E, Alqutaibi AY, Alhadainy H. Effect of apical patency on postoperative pain: A meta-analysis. J Endod 2018;44:1467-73. [CrossRef]
37. Nagendrababu V, Gutmann J L. Factors associated with postobturation pain following single-visit nonsurgical root canal treatment: a systematic review. Quintessence Int 2017;48:193-208.
38. Siqueira J F, Rôças I N, Favieri A, Machado A G, Gahyva S M, Oliveira J C, Abad E C. Incidence of postoperative pain after intracanal procedures based on an antimicrobial strategy. J Endod 2002;28:457-60. [CrossRef]
39. Williamson A, Hoggart B. Pain: a review of three commonly used pain rating scales. J Clin Nurse 2005;14:798-804. [CrossRef]
40. Price D D, Staud R, Robinson M E. How should we use the visual analogue scale (VAS) in rehabilitation outcomes? II: Visual analogue scales as ratio scales. J Rehabil Med 2012;4:800-1. [CrossRef]
41. Silva E J, Menaged K, Ajuz N, Monteiro M R, Coutinho-Filho de S. Postoperative pain after foraminal enlargement in anterior teeth with necrosis and apical periodontitis: a prospective and randomized clinical trial. J Endod 2013;39:173-6. [CrossRef]
42. Kara Tuncer A, Gerek M. Effect of working length measurement by electronic apex locator or digital radiography on postoperative pain: a randomized clinical trial. J Endod 2014;40:38-41. [CrossRef]


E
R