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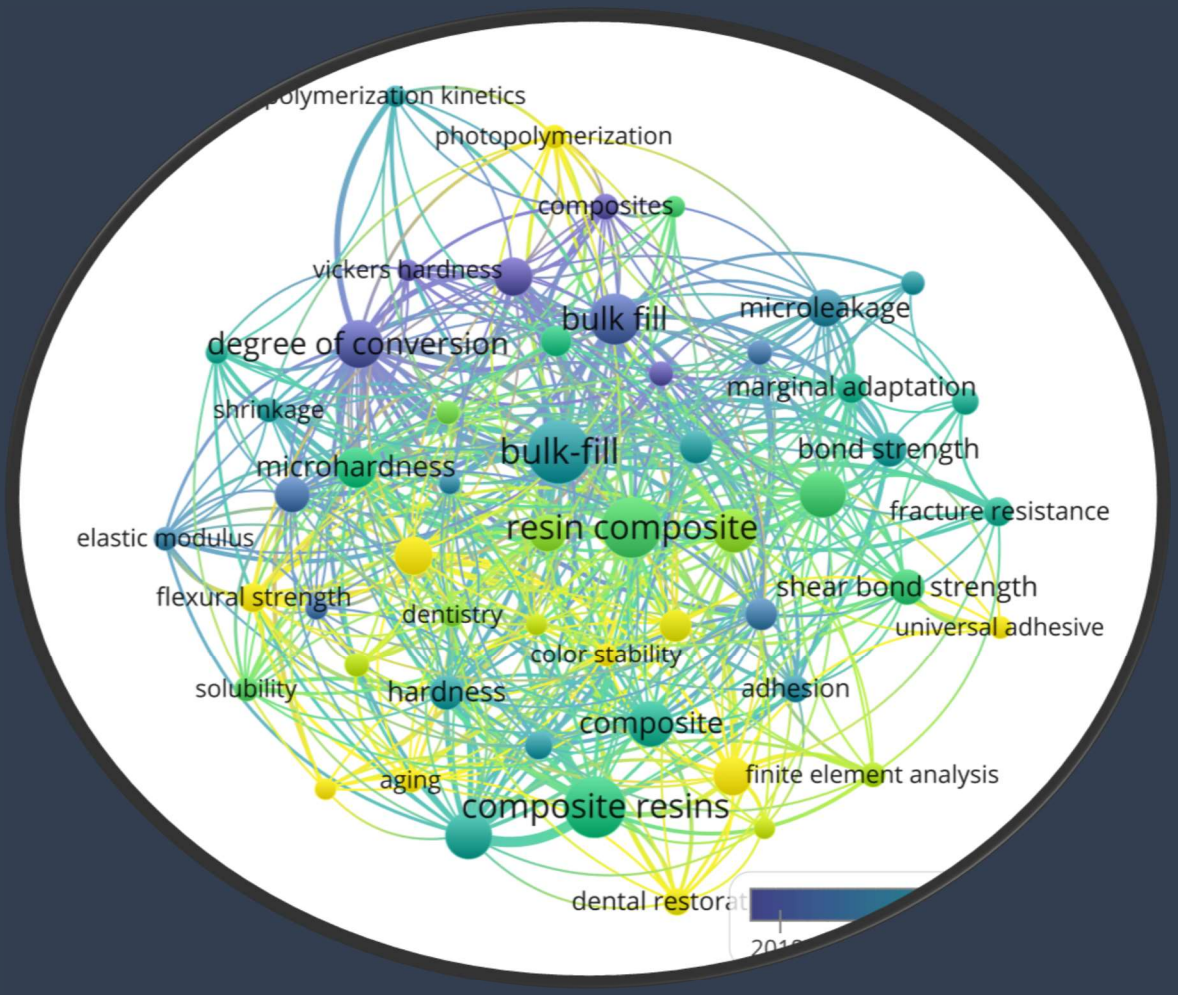

EndoRes

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Aims & Scope

Journal of Endodontics and Restorative Dentistry (J Endod Restor Dent) is a highly respected scientific journal that caters to the needs of those interested in the fields of endodontics and restorative dentistry. This online-only journal follows a rigorous and independent peer-review process, ensuring that all articles are unbiased and of the highest quality. The double-blinded approach employed by Journal of Endodontics and Restorative Dentistry further strengthens its credibility, making it a trusted source of information for researchers, practitioners, and students alike. With its biannual release schedule, readers can look forward to two new issues each year, in March and September. Overall, Journal of Endodontics and Restorative Dentistry is a valuable resource for anyone seeking to stay up-to-date on the latest developments in these important areas of dental science.

Journal of Endodontics and Restorative Dentistry provides extensive coverage of both clinical and experimental studies on all aspects of endodontics and restorative dentistry. Notably, the journal features original articles, reviews on current topics, case reports, editorial comments, and letters to the editor that follow ethical guidelines. It is important to note that the journal is published solely in English, ensuring it maintains a global reach and fosters international collaboration within the field.

The journal's editorial and publication processes are meticulously designed to meet the highest standards of integrity and quality. To ensure this, the journal adheres to the guidelines set by several reputable organizations such as the International Committee of Medical Journal Editors (ICMJE), World Association of Medical Editors (WAME), Council of Science Editors (CSE), Committee on Publication Ethics (COPE), European Association of Science Editors (EASE), and National Information Standards Organization (NISO). Furthermore, the journal is committed to upholding the Principles of Transparency and Best Practice in Scholarly Publishing, which have been laid out by the Directory of Open Access Journals (DOAJ) at doaj.org/bestpractice.

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JOURNAL of ENDODONTICS and RESTORATIVE DENTISTRY

Editorial

The Journal of Endodontics and Restorative Dentistry is officially commencing publication

Ömer Hatipoğlu [a]

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KEYWORDS

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ABSTRACT

The Journal of Endodontics and Restorative Dentistry is officially commencing publication. This new development will have a significant impact on the field of dentistry, as it will provide a platform for the dissemination of new research and findings in the areas of endodontics and restorative dentistry. This is a highly anticipated and welcome addition to the field, as it will undoubtedly serve as a valuable resource for researchers, practitioners, and students alike.

The fields of restorative dentistry and endodontics are critical to the overall practice of dentistry. However, there is a significant lack of trusted free publications that focus on these areas. To address this issue, the Journal of Endodontics and Restorative Dentistry (J Endod Restor Dent) was established with the primary goal of providing an accessible platform for sharing cutting-edge research and innovations in this specialized field. The journal aims to break down barriers and offer unrestricted access to valuable information, thus promoting the advancement of restorative dentistry and endodontics. Its comprehensive coverage of this specialized area ensures that dental professionals have access to the latest knowledge, techniques, and procedures, ultimately leading to better patient outcomes.

J Endod Restor Dent has started its journey with editors from five continents and sixteen different countries. Our diverse team of editors will help to distribute the journal, review the articles, and disseminate growing knowledge worldwide. We are committed to providing our readers with up-to-date and reliable information on the latest trends, discoveries, and practices in endodontics and restorative dentistry.

The journal's editorial and publication processes were meticulously designed to meet the highest standards of integrity and quality. To ensure this, we will adhere to the guidelines set by several reputable organizations such as the International Committee of Medical Journal Editors (ICMJE), World Association of Medical Editors (WAME), Council of Science Editors (CSE), Committee on Publication Ethics (COPE), European Association of Science Editors (EASE), and National Information Standards Organization (NISO). Furthermore, we want to uphold the principles of transparency and best practices in scholarly publishing laid out by the Directory of Open Access Journals (DOAJ).

In the field of editing, it is of utmost importance to ensure that the materials being published are apt and desirable, meeting the expectations of the intended audience. In order to ensure this, we established a strict policy of only accepting original contributions that add value to the reader, researcher, practitioner and the literature in general. Additionally, we will value the feedback provided by our readers, researchers, and practitioners and always strive to provide an informative response to their comments.

Our editorial team will take a thorough and comprehensive approach when evaluating articles for acceptance into our journal. We will carefully consider the article's importance, originality, validity, and clarity of expression, ensuring that it aligns with the goals and objectives of the publication. We will value the input of our reviewers and only disregard their feedback in cases where there are serious issues with the study. We will value our authors and provide them with descriptive and informative feedback, helping them to improve and refine their work.

J Endod Restor Dent will be an open-access journal that readers can access completely free of charge. This means that they would read, download, print, distribute, search, or link to the full texts of the articles without requiring permission from the publisher or author. The journal will follow the Budapest Open Access Initiative (BOAI) definition of open access, which means that the articles will be available to anyone who wishes to read them.

As a guardian of the academic record, the publisher bears an array of responsibilities. We will maintain high ethical standards with respect to research integrity, the application and review process, and publication. In addition, we want to give importance to the timely publication of content, including corrections, clarifications, and retractions. Furthermore, we will give attention to the preservation of published work.

Lastly, we invite you to submit your articles for publication in our esteemed journal. We welcome contributions to all aspects of endodontics and restorative dentistry, including but not limited to research, clinical practice, and education. We believe that your contributions will help to advance the field of endodontics and restorative dentistry and enhance the knowledge of our readers. Join us in this exciting journey, and let's work together to move the field of endodontics and restorative dentistry forward.

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JOURNAL of ENDODONTICS and RESTORATIVE DENTISTRY

Original Article

Bibliometric analysis of literature on Bulk-Fill Composite Resins in Dentistry

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CLINICAL SIGNIFICANCE

Over the past decade, there has been a rise in publications exploring bulk-fill composites. As these materials allow for deeper polymerization, research into their properties

ABSTRACT

Objectives: Bulk-fill composite resins, offer a simplified application process through the use of a single layer, saving valuable time and effort. This study aimed to Identify of all research areas, the most effective authors, countries, and journals about bulk-fill composite resins in the period of 2011-2022.

Materials and methods: Electronic research was conducted in the Web of Science database by selecting the words "bulk-fill composite" and "restoration". Bibliometrics were extracted and analysed using VOSviewer v1.6.14. To analyze the most frequently cited articles, a spreadsheet, where equal weight was given to each collaborator's contribution was used. VOSviewer helped to visualize the citation network and collaboration.

Results: The largest number of publications on bulk-fill appeared in 2021, and the most frequently cited work covers the subject of mechanical properties of the bulk-fill composite. Most articles on bulk-fill come from Brazil, and the researcher from Germany has achieved the greatest achievements in this field. David Craig Watts is identified as the author with the highest number of published works, whereas Nicoleta Ilie is recognized for receiving the most citations for her work. King Saud University produced the most publications with a total of 56, while the University of Munich was found to have received the highest number of citations, totalling 1672.

Conclusion: This bibliometric analysis illustrates the progress and trend of bulk-fill composite research. The results can be an excellent reference for identifying unexplored areas of knowledge and provide excellent tips on creating high-cited papers.

1. Introduction

Bibliometrics is a systematic method for evaluating research output to analyse literature using statistical and mathematical approaches. For several years, bibliometric analyses have been used in various fields of science to map publications and create a broader context of the analysed topic. Bibliometrics is a great tool to represent the historical development of research fields and evaluate the research productivity of journals, researchers, universities, countries, and many other organisations. Citation analysis, which examines the effect of research publication by examining citation data obtained by a scientific study, is the preferred method in bibliometry.[1,2] One limitation of this analysis is the publication time. Older articles are more likely to be cited. This is certainly a shortcoming of citation analysis, but today it maintains its popularity for measuring the attribution effect of an article. Equally helpful in analysing the topic can be a systematic review or meta-analysis. These are techniques for searching, evaluating, synthesising research evidence and combining quantitative research results on a given topic. Their limitation is certainly the narrow scope of the researched topic.

Due to their short history, bulk-fill composite materials are a perfect topic for knowledge mapping. In a short time, they have gained tremendous popularity among dentists worldwide.[3,4] Bulk-fill materials are characterised by a chemical composition that reduces polymerisation shrinkage. Consequently, they can be applied in a thicker layer than classic composite materials. This feature means they can be used in conservative dentistry in two ways - either to obtain a more durable filling with layer application or to shorten the procedure of filling a cavity with one layer application. The first solution is used for the conservative reconstruction of posterior teeth in adult patients, and the second option is worth using in the case of children and adults during procedures of prolonged duration.[5,6]

Due to the great interest in the subject of bulk-fill composite, it is necessary to discover new relationships that have not yet been established, continue the research undertaken to update them, and sometimes even change the existing theories.

Until now, no complete bibliometric analysis of bulk-fill composites has been found in the literature. Our analysis of topics related to bulk-fill materials can help systematise knowledge, reveal missing research areas, and help scientists plan better research and publications. Nowadays, scientists are required to deliver high-cited papers. The bibliometric analysis seems to be a suitable tool for this purpose.

2. Materials and Methods

The search was performed through the Web of Science, a repository of top-notch literature resources owned by Clarivate. To enhance the precision of the search, the topic field was restricted to the keywords, abstract and title.

A search was conducted in June 2023 to locate articles on bulk-fill composites in dentistry. The search parameters were limited to articles published before December 31, 2022, specifically focusing on this topic. Only studies classified as "article", "proceeding paper", "review", or "early access" were selected, except for those published before 2011 (because bulk-fill composites were first introduced to the market in 2011). Additionally, all citation topics, except for 1.49 Dentistry & Oral Medicine from meso, were excluded.

Exporting the search results has been undertaken in a tab-delimited format and subsequently subjected to a meticulous analysis using VOSviewer v1.6.14, a bibliometric software program from the Leiden University's Center for Science and Technology Studies. This software program has facilitated comprehensive scrutiny of various parameters such as authors, affiliations, keywords, abstracts, titles, references, and countries. Furthermore,

pertinent data from the WoS functions of "analyse results" and "citation report" have been judiciously collated to supplement the analysis.

Data extraction, processing, and summarisation were conducted utilising Microsoft Office 2016 Excel and VOSviewer. The most frequently cited articles were analysed using a spreadsheet, with equal weight allotted to every collaborator's contribution. Visualising the citation network and collaboration was facilitated by VOSviewer. In the map, the size of the bubble indicated the number of publications, while the distance between bubbles demonstrated their relatedness. The colour of the bubble held varying meanings, depending on the visualisation employed. Network visualisation showed that the same-coloured bubbles formed clusters, indicating close collaboration in research output. Detailed information regarding these findings is available within the figure legends.

An analysis was conducted to assess the impact of keywords on publications. The methodology employed was akin to that of previous research.[7] A publication's relative citation score was determined by using a formula that divided the citation count of a publication by the average citation count of all publications during a specific time frame. Any publication with a score above 1 was deemed to have received more citations than the average. In order to calculate the normalised citation score for each term, the average of the normalised citation scores of all publications that contained the specific term was taken. This calculation was facilitated through the VOSviewer software program and its term map visualisations.

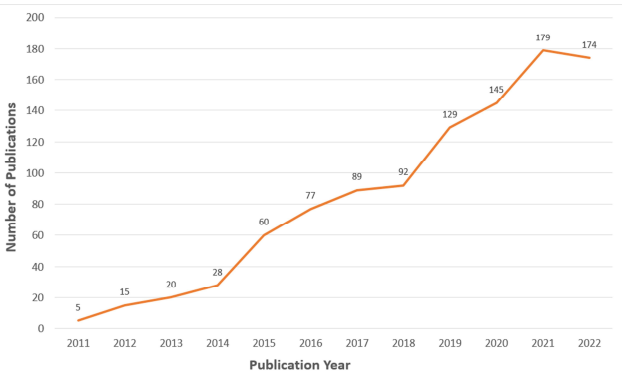

Fig 1. Number of research according to Publication year

3. Results

A comprehensive search was performed using the Web of Science database and found a total of 1013 studies that were

Table 1. Information about the top 20 most cited articles related to research on bulk-fill Composites.

	Title	Authors	Journal	Publication Year	Total Citations	Average per Year
1	Bulk-fill Resin-based Composites: An In Vitro Assessment of Their Mechanical Performance	Ilie, N.; Bucuta, S.; Draenert, M.	Operative Dentistry	2013	247	22.45
2	Physico-mechanical characteristics of commercially available bulk-fill composites	Leprince, J. G.; Palin, W. M.; Vanacker, J. et al.	Journal of Dentistry	2014	215	21.50
3	Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites	Bucuta, S.; Ilie, N.	Clinical Oral Investigations	2014	209	20.90
4	Depth of cure of resin composites: Is the ISO 4049 method suitable for bulk fill materials?	Flury, S.; Hayoz, S.; Peutzfeldt, A. et al.	Dental Materials	2012	179	14.92
5	In vitro comparison of mechanical properties and degree of cure of bulk fill composites	Czasch, P.; Ilie, N.	Clinical Oral Investigations	2013	178	16.18
6	Polymerization Shrinkage Stress Kinetics and Related Properties of Bulk-fill Resin Composites	El-Damanhoury, H. M.; Platt, J. A.	Operative Dentistry	2014	170	17.00
7	Bulk-fill resin composites: Polymerization properties and extended light curing	Zorzin, J.; Maier, E.; Harre, S. et al.	Dental Materials	2015	160	17.78
8	Cuspal deflection and microleakage in premolar teeth restored with bulk-fill flowable resin-based composite base materials	Moorthy, A.; Hogg, C. H.; Dowling, A. H.; Grufferty, B. F.; Benetti, A. R. et al.	Journal of Dentistry	2012	160	13.33
9	Physical properties and depth of cure of a new short fiber reinforced composite	Garoushi, S.; Sailynoja, E.; Vallittu, Pekka K.; Lassila, L.	Dental Materials	2013	154	14.00
10	Degree of conversion of bulk-fill compared to conventional resin-composites at two time intervals	Alshali, R. Z.; Silikas, N.; Satterthwaite, J. D.	Dental Materials	2013	148	13.45
11	Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites	Kim, R.; Kim, Y.; Choi, N. et al.	Journal of Dentistry	2015	146	16.22
12	Bulk-Fill Resin Composites: Polymerization Contraction, Depth of Cure, and Gap Formation	Benetti, A. R.; Havndrup-Pedersen, C.; Honore, D. et al.	Operative Dentistry	2015	141	15.67
13	Bulk-Fill Composites: A Review of the Current Literature	Van Ende, A.; De Munck, J.; Lise, D. P. et al.	Journal of Adhesive Dentistry	2017	140	20.00
14	Translucency of esthetic dental restorative CAD/CAM materials and composite resins with respect to thickness and surface roughness	Awad, D.; Stawarczyk, B.; Liebermann, A. et al.	Journal of Prosthetic Dentistry	2015	140	15.56
15	Post-cure depth of cure of bulk fill dental resin-composites	Alrahlah, A.; Silikas, N.; Watts, D. C.	Dental Materials	2014	137	13.70
16	Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites	Fronza, B.; Rueggeberg, F.; Braga, R. et al.	Dental Materials	2015	135	15.00
17	Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique	Rosatto, C. M. P.; Bicalho, A. A.; Verissimo, C.; Braganca, G. F. et al.	Journal of Dentistry	2015	128	14.22
18	Marginal quality of flowable 4-mm base vs. conventionally layered resin composite	Roggendorf, M. J.; Kraemer, N.; Appelt, A. et al.	Journal of Dentistry	2011	127	9.77
19	Effect of layering methods, composite type, and flowable liner on the polymerization shrinkage stress of light cured composites	Kwon, Y.; Ferracane, J.; Lee, I.	Dental Materials	2012	125	10.42
20	Bulk-filling of high C-factor posterior cavities: Effect on adhesion to cavity-bottom dentin	Van Ende, A.; De Munck, J.; Van Landuyt, K. L. et al.	Dental Materials	2013	123	11.18

Table 2. Top 10 Productive and cited Authors

Top 10 Productive Authors				Top 10 Cited Authors			
Authors	**Institution**	**Country**	**No of articles**	**Authors**	**Instutuion**	**Country**	**No of citations**
Watts, David Craig	University of Manchester	England	32	Ilie, Nicoleta	University of Munich	Germany	1400
Giannini, Marcelo	Universidade E. de Campinas	Brazil	30	Silikas, Nick	University of Manchester	England	1107
Ilie, Nicoleta	University of Munich	Germany	29	Watts, David Craig	University of Manchester	England	1046
Price, Richard B.	Dalhousie University	Canada	26	Giannini, Marcelo	Uni. Estadual de Campinas	Brazil	617
Silikas, Nick	University of Manchester	England	24	Van Meerbeek, Bart	University Hospital Leuven	Belgium	540
Soares, Carlos José	Universidade Federal de Uberlândia	Brazil	22	de Munck, Jan C.	University Hospital Leuven	Belgium	528
Tarle, Zrinka	University of Zagreb	Croatia	19	Garoushi, Sufyan	University of Turku	Finland	442
Attin, Thomas	University of Zurich	Switzerland	17	Vallittu, Pekka K.	University of Turku	Finland	386
Taubock, Tobias T.	University of Zurich	Switzerland	17	Alshali, Ruwaida Z.	King Abdulaziz University	Saudi Arabia	383
Marovic, Danijela	University of Zagreb	Croatia	16	Palin, William M.	University of Birmingham	England	342

published between 2011 and 2023. The data indicates a consistent upward trend in the number of articles published annually, with a marked increase after 2014 (Fig. 1). However, a decline in publication activity is observed in 2021. Out of the 1013 publications, the majority of articles fell under the categories of Dentistry, Oral Surgery Medicine (n=683, 67.42%), Materials Science (n=293, 28.92%), Engineering (n=90, 8.88%), and Chemistry (n=53, 5.23%).

The combined citations for publications on bulk-fill composites amounted to 14,934. With an h-index of 56, each article received an average of 14.74 citations. Twenty-five of the publications were cited more than 100 times. Table 1 displays the 20 most cited papers.

According to data presented in Table 2, a total of 3153 authors contributed to the articles analysed, with an average of 3.11 authors per article. Analysis of the network of collaborations, as illustrated in Fig. 2A, reveals that highly productive authors were at the centre of the network. Among them, David Craig Watts emerged as the most prolific author, while Nicoleta Ilie's work garnered the highest number of citations. Notably, four scholars: David Craig Watts, Giannini Marcelo, Nicoleta Ilie, and Nick Silikas, were included in both lists, indicating their exceptional productivity and influence in this field.

The literature on bulk-fill composites received contributions from 902 organisations across 71 countries or regions. As per Table 3, it was noted that King Saud University produced the most publications, with a total of 56, while the University of Munich received the highest number of citations, totalling 1672. Most of the studies were conducted in universities, with the University of Manchester showing a high citation rate per article. Figure 2B revealed several clusters of institutions centred on King Saud University, the University of Zurich, Universidade Estadual de Campinas, and King Abdulaziz University.productivity and influence in this field.

As illustrated in Table 4, Brazil has acquired the largest share of articles, amounting to 21.62%, corresponding to 219 articles. Turkey and the USA are closely behind, commanding 16.19% with 164 papers each. It is noteworthy that the USA has received the highest number of citations, amounting to 3030, whereas Brazil and Germany trail behind with 2688 and 2472 citations, respectively. When scrutinising international collaborations, it has been observed that Brazil, Turkey, the USA, and Saudi Arabia have received the most extensive attention, as indicated in Figure 2C.

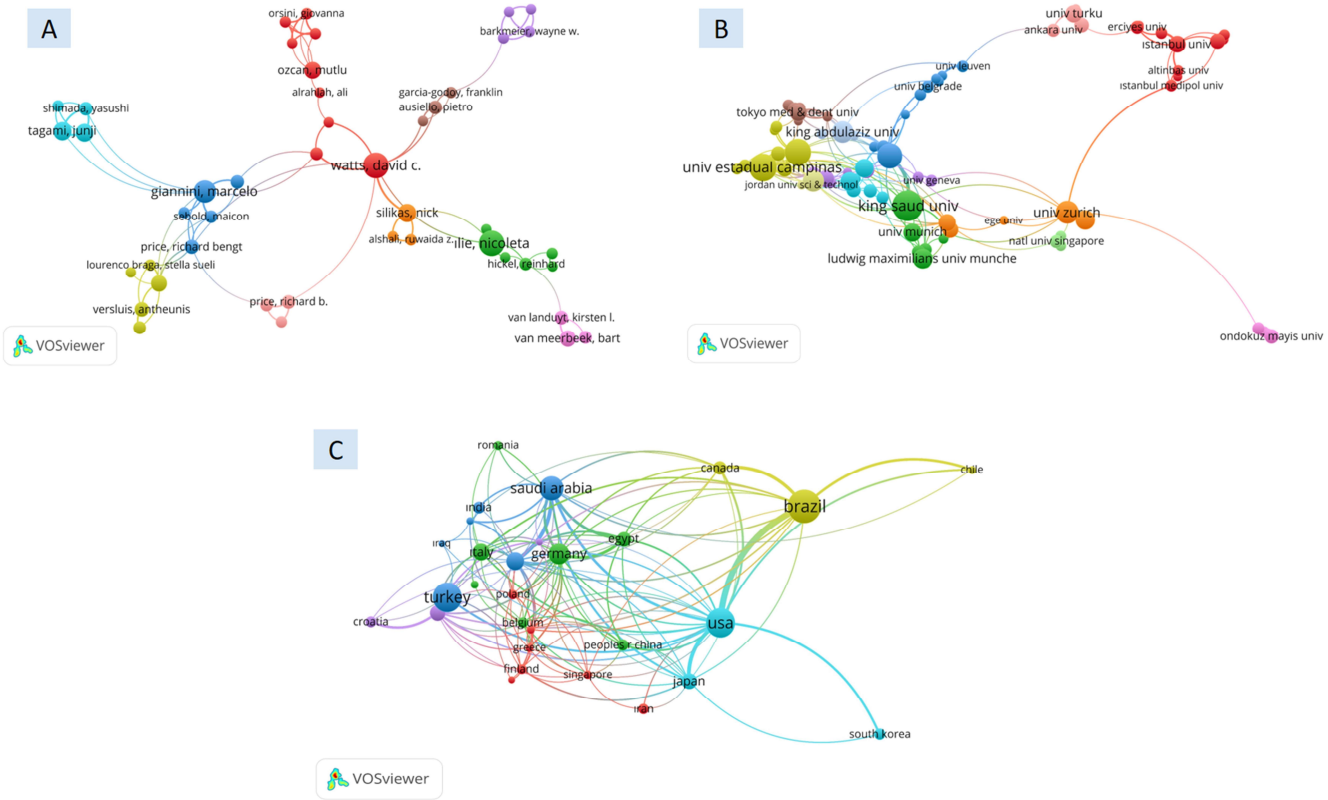

Fig 2. The chart shows collaboration networks based on publications. The bubbles represent authors (A), institutions (B), or countries/regions (C) depending on the category, with larger bubbles indicating a higher number of publications. The links between bubbles indicate the level of collaboration, with shorter links indicating closer collaboration. Only those with more than 5 publications (authors) or 10 publications (institutions and countries/regions) are included in the chart.

Table 3. Top 10 contributing institutions

Institution	Country	Number of Articles	Number of Citations	Citations per Article	H-Index
King Saud University	Saudi Arabia	56	898	16.04	15
University of Munich	Germany	49	1672	34.12	21
Universidade Estadual de Campinas	Brazil	48	836	17.42	15
N8 Research Partnership	England	42	1544	36.76	23
Universidade Sao Paulo	Brazil	41	804	19.61	16
Egyptian Knowlege Bank EKB	Egypt	38	630	16.58	13
University of Manchester	England	38	1435	37.76	23
University of Zurich	Switzerland	31	466	15.03	11
Universidade Estadual Paulista	Brazil	30	316	10.53	9
King Abdulaziz University	Saudi Arabia	28	536	19.14	9

Of the 203 journals with publications on bulk-fill composites, only two have published over 100 articles on the subject. These journals are Operative Dentistry, which accounts for 106 publications (10.46%), and Dental Materials, which accounts for 101 (9.97%). Additionally, the Journal of Dentistry published 50 articles (4.94%), and Clinical Oral Investigations published 44 (4.34%). While Operative Dentistry was the most productive regarding the number of publications, Dental Materials and Journal of Dentistry had higher average normalised citations, as illustrated in Figure 3.

The term map for keywords showed which words were used most frequently in publications about bulk-fill composites. The top keyword was "bulk-fill," appearing 90 times. "Composite resins" was the second most used word with 84 occurrences, followed by "resin composite" with 81, "bulk fill" with 58, and "degree of conversion" with 51 (Fig. 4).

4. Discussion

Bulk-fill composites are currently one of the most popular materials for reconstructing posterior teeth. Since 2011 it was introduced to use, and the number of publications on this subject has been growing. Thanks to their mechanical properties and easy restoration procedure, they are present in almost every dental office. Figure 1 shows the number of articles per year. The slight decline after 2021 may be due to the COVID-19 pandemic, which affected all aspects of society. Researchers worldwide are still working to provide new solutions and better understand this occurrence.[2,8] Due to a large number of bulk-fill publications, Table 1 lists the twenty most cited articles and analyses their main features. In this study, the most common article type used is an original article - a scientific article presenting the results of original research of an empirical, theoretical, technical or analytical nature. The subject of physicochemical properties is particularly exploited; the three most cited articles on bulk-fill relate to this area of research.[3,9,10] Another topic of particular interest to researchers is bulk-fill polymerisation. The degree of conversion, irradiation depth and polymerisation shrinkage were analysed.[11-13] The next highly cited topic is the 4mm layer thickness of the application.[14-16] The range of analysed topics is also presented in a graphical form, allowing for a quicker visual assessment, especially for researchers planning new research projects (Fig.4). Among the most cited articles, those based on surveys are missing. This may indicate that scientists do not value surveys or that there is a lack of good survey research. The second hypothesis seems to be more proper. There is a lack of scientific articles based on well-designed and wide-ranging surveys, e.g., conducted in many countries with different economic and health development levels. This may be another clue for future researchers.

It seems that the clinical aspects of working with bulk-fill composite are still unexplored. Among other things, the literature does not answer which polymerisation mode is best for bulk-fill. Manufacturers of polymerisation lamps release new models yearly, so the need to research the subject is still valid. The same problem is with the finishing of this material. How to polish the bulk-fill composite to get the best durability of the filling?

Another thing is that the best-cited scientific papers usually present the results of complicated physicochemical analyses, often incomprehensible to the average clinician.[17-19] Consequently, only other scientists are interested in scientific results. Maybe it would be worth trying to bring this advanced science closer to an ordinary dentist but in a more accessible way.

Our analysis showed that most bulk-fill articles come from Brazil (Table 4). Ülkü et al.[1] noticed a similar relationship in their analysis of reports about the conventional composite. Turkey and the USA are also very active countries, which is also determined and confirmed by Ülkü et al.[1]

According to Yang et al.[20], an article with≥400 citations is considered a "classic" article. In our work, the best-cited articles ranged between 247 and 123. Perhaps the next decade will significantly increase the citation rate, and bulk-fill articles will become classics.

International research cooperation is the foundation of modern higher education and science systems. The number and percentage of internationally co-authored publications, as does the average distance between collaborating scientists, continues to grow. The data best illustrate the huge scale of international cooperation in global terms: in the years 1996–2018, the share of publications indexed in the Scopus database with authors from at least two countries almost doubled, from 24.2% to 45.7%, and their number increased almost quadrupled from 75,000 to 279,000 items per year.[21] The global scientific model has a strong pull effect on scientists and is supported by new indicators used in individual and institutional research quality assessment procedures. Thus, while the role of national collaboration is weakening, the role of international cooperation seems to be growing. Our analysis showed that countries such as Brazil, Turkey, the USA and Saudi Arabia seem to be the best candidates for international cooperation.

Table 4. Top 10 contributing institutions

Country	Number of Articles	Proportion of Articles (%)	Number of Citations	Citations per Article	H-Index
Brazil	219	21.62	2688	12.27	27
Turkey	164	16.19	1083	6.6	17
U.S.A	164	16.19	3030	18.48	30
Saudi Arabia	117	11.55	1690	14.44	23
Germany	88	8.687	2472	28.09	24
England	65	6.417	2125	32.69	27
Italy	56	5.528	882	15.75	18
Japan	49	4.837	623	12.71	14
Switzerland	48	4.738	873	18.19	15
Egypt	41	4.047	638	15.56	13

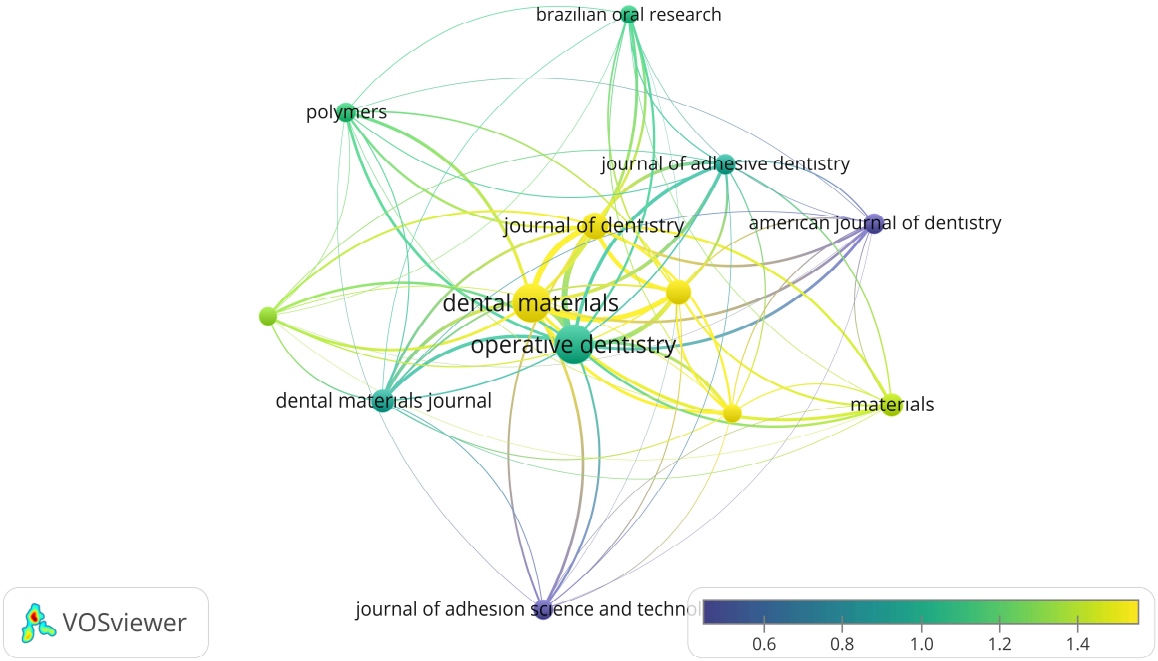

Fig 3. The chart displays a citation map of a journal, with larger bubbles indicating a higher number of publications. The yellow colour represents a higher average normalised citation, while blue represents a lower one. Only journals with more than 20 publications were included in the analysis.

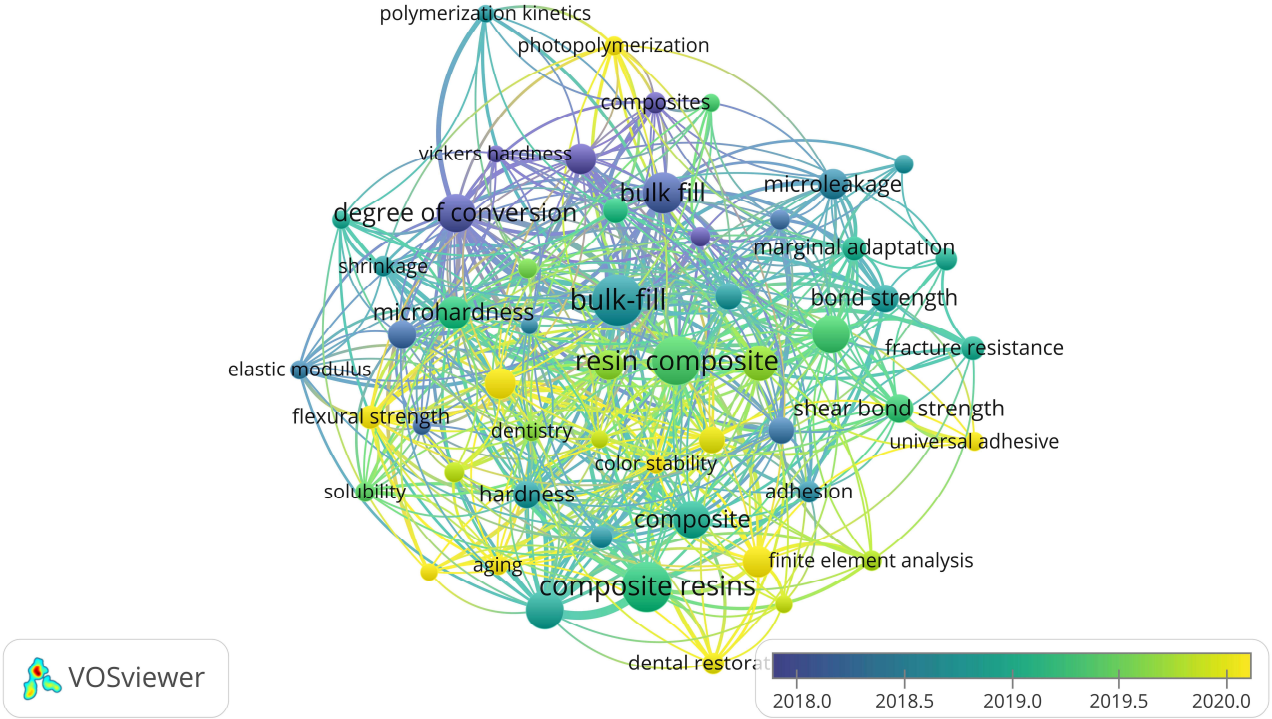

Fig 4. The chart displays a map of keywords, with larger bubbles indicating a higher number of publications. The yellow colour represents a higher average publication year, while blue represents a lower one. Only journals with more than 10 publications were included in the analysis.

The journals listed in our analysis (Fig.3), such as Operative Dentistry, Dental Materials, Journal of Dentistry, Polymers, and Clinical Oral Investigations are among the most read and recognised worldwide. The requirements for authors are understandable and logical, and the publication procedure is very transparent. When choosing a journal for publication, it is worth taking into account the index values and the speed of reviews and publication.

There are some limitations in this bibliometric analysis. Only Web of Science database was analysed. Not all scientific books, articles or conference proceedings have been included in the Web of Science. In the future, analysis of other databases, such as Scopus and GoogleScolar, is planned to compare the differences. Second, almost all Web of Science reports are in English, which can generate language bias and ignore other languages. Thirdly, the number of citations may or may not reflect the article's impact on the scientific world.

5. Conclusion

In summary, within the limitations of this study, the bibliometric provides a helpful perspective on the impact and changing research trends of bulk-fill composites over the past 11 years. Perhaps new digital tools will soon be created for an even better analysis of the impact of a given scientific work on the reality that surrounds us.

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CRediT Author Statement

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Original Article

Evaluation of Maxillary First Molar Teeth's Mesiobuccal Root and Root Canal Morphology using two classification systems amongst a Turkish population: A Cone-beam Computed Tomography study

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CLINICAL SIGNIFICANCE

Clinicians must possess knowledge regarding the prevalence and nature of additional canals in the mesiobuccal roots of maxillary first molars across varying populations. Failure to address this issue can lead to treatment failure and unsatisfactory outcomes for patients.

ABSTRACT

Objectives: This research aimed to analyze and compare the morphology of the mesiobuccal (MB) root and its canals in maxillary first molars (M1Ms) using Vertucci (1984) and Ahmed et al. (2017) classification systems.

Materials and Methods: 250 cone beam computed tomography (CBCT) images of 500 M1M teeth were evaluated for MB root and canal configurations. The images were analyzed from sagittal, axial and coronal perspectives. Canal number and morphology were documented according to Vertucci's method as well as a more recent classification system.

Results: The majority of MB roots had Type I morphology according to the Vertucci classification (right: 38.4%; left: 43.2%), and according to the new root canal morphology classification system, the most common code detected was ^{3}16 MB^{1} in the right side (37.6%), ^{3}26 MB^{1} for the left side (41.2%). Subsequently, Type IV (right: 24.4%; left: 26.0%) and Type V (right: 16.4%; left: 14.4%) were the next most frequently identified morphologies according to the Vertucci classification, whereas according to Ahmed's classification ^{3}16 MB^{2} (24.4%), ^{3}26 MB^{2} (25.2%), ^{3}16 MB$^{1-2}$ (16.4%), and ^{3}26 MB$^{1-2}$ (14.0%) were the most common.

Conclusion: It is vital for dentists to locate and treat all parts of a tooth, especially the MB2 canals in M1Ms, to prevent endodontic treatment failure due to microbial contamination and infection. For clinicians seeking clarity in root and canal morphology, the new classification system offers a more precise and user-friendly approach than the traditional Vertucci classification.

1. Introduction

The development of teeth is a series of complex biological processes governed by epithelial-mesenchymal interactions. Disruption of these interactions during the developmental process can alter the normal course of odontogenesis and lead to developmental anomalies and variations.[1] Depending on the developmental stage of the tooth, several variations may occur in the number, size, and/or shape of roots/canals. Studies have shown that these variations can differ significantly among populations, within populations, and even within the same individual.[2] Achieving success in endodontic procedures hinges on the effective cleaning, shaping, and filling of the root canal system. A profound understanding of root canal morphology is vital to ensure the right treatment approach. Thus, radiographic evaluation is indispensable in diagnosing and strategizing treatments for root canals.[3]

Various systems are available to classify root canals and accessory canal morphologies.[4,5] Weine, et al. [6] utilized cross-sectional and radiographic methods to initially divide root canal configurations within a single root into three types, and later, one more type was added. Vertucci, et al. [5] used the clearing technique to identify internal root canal anatomy and proposed a more complex classification, with a total of eight configurations. Despite these efforts to systematically define variations in canal configurations, variations in root canal morphology have been observed in different populations.[2,7] Versiani, et al. [4] using micro-CT technology, described 37 types of root canal configurations within a single root. With the increasing range of anatomical variations and the more apparent shortcomings of the existing systems, Ahmed et al.[8] proposed a more comprehensive system for the classification of the root, root canal, and accessory canal morphologies. Recent scholarly investigations have consistently highlighted that the system developed by Ahmed et al. not only possesses broader applicability but also excels in accuracy.[9-11]

Traditional methods used to analyze the root canal morphology (such as sectioning, canal staining, and clearing technique) are generally invasive and require special preparation.[12] Although periapical radiography is one of the most important diagnostic tools in endodontic treatment, it may fail to provide accurate information regarding variations due to superimpositions.[13] Cone-beam computed tomography (CBCT) allows a three-dimensional view of root canals from different angles in a 360-degree axis, enabling a more precise analysis of the root canal anatomy.[14] Additionally, it provides a high-quality image with lower radiation exposure compared to traditional CT scans. Micro-computed tomography (micro-CT) is another diagnostic tool that provides more detailed information about root and canal morphology compared to CBCT, but it is expensive, time-consuming, and not currently suitable for clinical use.[15] This CBCT study aims to comparatively evaluate the morphology of the mesiobuccal (MB) root and root canals of maxillary first molars (FDI tooth #16 and 26) using two classification systems (Vertucci, et al. [5] and Ahmed, et al. [8]).

For clinicians, an in-depth understanding of diverse root and root canal structures is paramount. Recognizing and managing these variations correctly during root canal treatments is essential to enhance treatment outcomes. This research was conducted to investigate the root anatomy and canal patterns of M1Ms using CBCT scans to evaluate the reliability and accuracy of different

systems for both educational and clinical practice. Moreover, the study aimed to discern if these patterns demonstrated variations based on age or sex.

2. Materials and Methods

2.1. Data collection

In this cross-sectional retrospective study, a total of 250 CBCT images (125 females, 125 males) taken between January 2022 and June 2023 for various diagnostic reasons were used to evaluate the MB root and root canal configurations of permanent M1Ms. Ethical approval for the study was obtained from the Ethics Committee of the Faculty of Dentistry, Necmettin Erbakan University, for non-drug and non-medical device research. All revisions were conducted in accordance with the principles outlined in the Helsinki Declaration.

Using the G-power 3.1.9.4 software program, the sample size was calculated to be at least 188 individuals at a 95% confidence level, α=0.05, power (1-β)=0.95 according to the differences between two independent proportions.[16]

Samples were selected according to the following criteria:

- CBCT images of sufficient diagnostic quality
- Patients with bilateral M1Ms aged 16-70 years
- Teeth with intact or minor caries lesions/restoration and complete root development.

Images of teeth with root canal treatment, post-core restorations, crowns, resorptive defects, internal calcifications, or fractures in the maxillary posterior region were excluded from the study.

2.2. Cone-beam computed tomography

CBCT data were obtained from a CBCT machine (J Morita MFG. Corp., 3D Accuitomo 170, Kyoto, Japan) with exposure parameters of 90 kVp and 5 mA for 17.5 seconds scanning time, and a voxel resolution of 0.250 mm with a field of view of 10x10 cm. The examinations were performed using the i-Dixel One Data Viewer imaging software (J Morita MFG Corp., Kyoto, Japan) on a 27-inch color Ultra Sharp LED TFT display (Dell, Dell Inc. Round Rock, TX, USA) with a resolution of 2560 x 1440 and 3.7 MP. To obtain appropriate visualization, contrast and brightness of the images were adjusted using image processing tools. The root number and MB root canal morphology of maxillary first molars were determined using different planes (coronal, axial, and sagittal).

2.3. Calibration

Calibration for this study was performed twice, one week apart, by an oral and maxillofacial radiologist with six years expertise

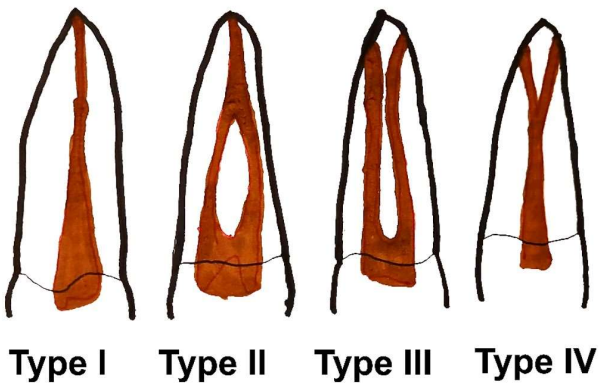

Fig 1. Weine's classification for root canal morphology

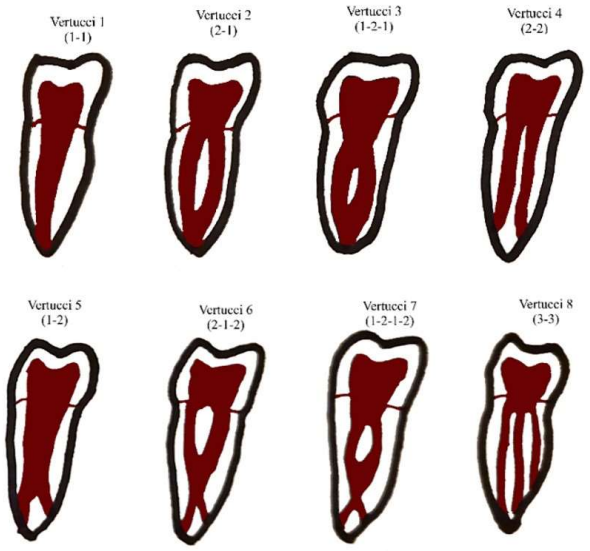

Fig 2. Vertucci's classification for root canal morphology

(SU). The expert was instructed to evaluate 50 CBCT scans. These scans were analysed from axial, sagittal and coronal perspectives and the root canal morphology was reported according to the classifications established by Vertucci and Ahmed. Intracorrelation coefficiant (ICC) values were calculated for intraobserver agreement. The kappa values were 0.86 and 0.80 for Vertucci and Ahmed et al. classifications.

2.4. Root canal analysis

The obtained images were grouped according to the patient's age (10–20, 21–30, 31–40, 41–50, over 51 years) and gender (female and male). The MB root canal morphology of the permanent maxillary first molars was evaluated separately according to the classification systems of Vertucci, et al. [5] (Fig. 1) and Ahmed, et al. [8] (Fig. 2-5). In the presence of anomalies, 6-category classification of Zhang, et al. [17] for root fusion and 3-category classification of Fan, et al. [18] for C-shaped canals were used.

2.4. Statistical Analysis

SPSS version 26 (IBM Corp., Armonk, NY, USA) software was used for data entry and statistical analysis. Descriptive statistics such as frequency, mean, and standard deviation were calculated. The chi-square test was used for data analysis, and the significance level set at 0.05 ($p<0.05$).

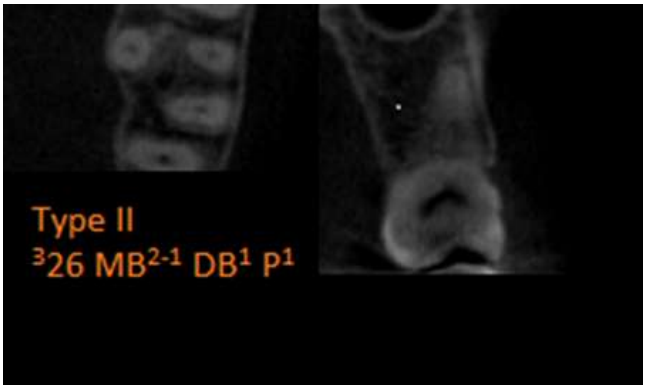

Fig 3. CBCT images demonstrating root canal morphological variations of three-rooted maxillary molar tooth using the two systems [above – Vertucci classification; below – new system (Ahmed et al. 2017)]; 26: Maxillary left first molar, MB: Mesiobuccal, DB: Distobuccal, P: Palatal.

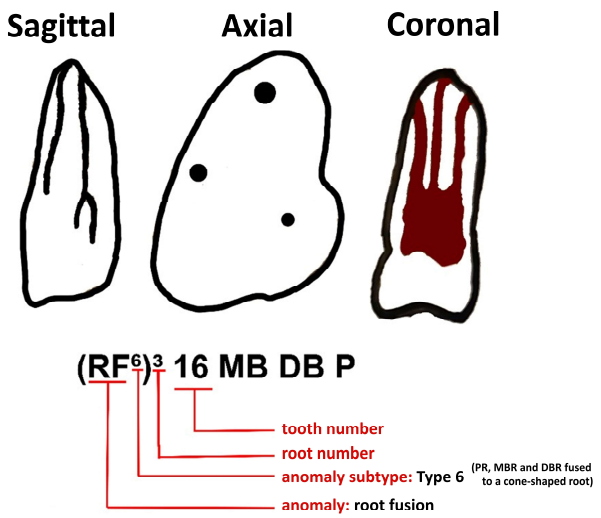

Fig 4. Coding of root canal morphology of maxillary molar tooth with root fusion (RF) according to the Ahmed et al. classification

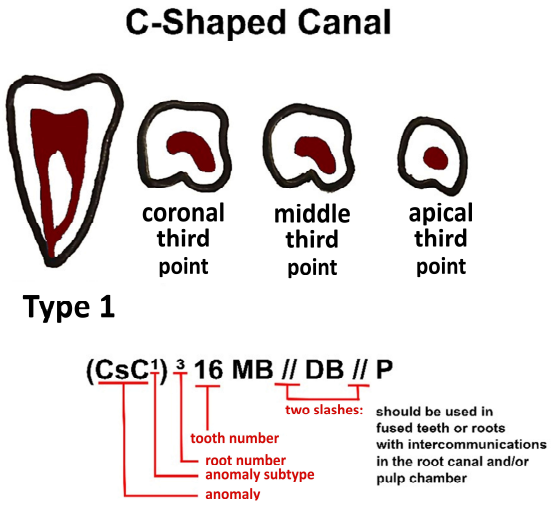

Fig 5. Ahmed et al. classification in C-shaped canals(CsC)

3. Results

The distribution of all evaluated CBCT images according to age groups and sex is shown in Fig. 6. A total of 500 MB roots of permanent M1Ms were examined in 250 CBCT images. The largest age group among the participants was 21-30 years old (n=75). There was no statistically significant difference in the sex distribution among the age groups (p=0.685). According to Vertucci, et al. [5] and the new classification systems [8], Table 1 shows the distribution of the number of roots and MB root morphologies of permanent M1Ms according to age and sex.

Most of the maxillary first molars had three roots (right side: 99.2%; left side: 96.4%) (Table 2). There was no statistically significant difference in the number of roots based on sex and age groups (p>0.05) (Table 2).

The majority of MB roots had Type I morphology according to the Vertucci classification [5] (right side: 38.4%; left side: 43.2%), and according to the new root canal morphology classification system, the most common code detected was $^{3}16\ MB^{1}$ in the right side (37.6%), $^{3}26\ MB^{1}$ for the left side (41.2%). Subsequently, Type IV (right 24.4%; left 26.0%) and Type V (16.4%; left 14.4%) were the next most frequently identified morphologies according to the Vertucci classification, whereas according to Ahmed's classification $^{3}16\ MB^{2}$ (24.4%), $^{3}26\ MB^{2}$ (25.2%), $^{3}16\ MB^{1-2}$ (16.4%), and $^{3}26\ MB^{1-2}$ (14.0%) were the most common. Three teeth (1.2% for both right and left sides) were encountered that were not specified in the Vertucci classification and were coded as "other". In Ahmed's classification, four teeth each (0.4% for both right and left sides) showed root fusion bilaterally, one tooth on the right side (0.4%), and two teeth on the left side (0.8%) exhibited C canal anomalies. In maxillary molars with no anomalies in the MB roots, the least common morphologies (0.4%) were $^{3}16\ MB^{3}$ and $^{1}16\ MB^{1-2-1-2}$ for the right side, and $^{3}26\ MB^{2-1-2-3-2}$ and $^{3}26\ MB^{1-2-3}$ for the left side. According to both Vertucci and Ahmed's classifications, there was no statistically significant difference in root morphologies based on sex and age (p>0.05) (Table 2). 16 $(RF^{7})^{4}\ MB1^{1}\ MB2^{1}$ (0.4%), 16 $(CsC^{1})^{4}M//D//P$ (0.4%), 26 $(RF^{6})^{3}MB^{1}$ (0.4%), 26 $(RF^{7})^{4}\ MB1^{1}\ MB2^{1}$ (1.2%), 26 $(CsC^{1})^{4}M//D//P$ (0.8%) were also detected in the MB roots of M1Ms according to the new classification (Table 2).

Table 1: Ahmed et al. codes summary allocated for tooth type

Type of tooth	Classification
Single-rooted	$^{1}TN^{O\text{-}C\text{-}F}$
Double-rooted	$^{1}TN\ R1^{O\text{-}C\text{-}F}R2^{O\text{-}C\text{-}F}$
Multirooted	$^{1}TN\ R1^{O\text{-}C\text{-}F}R2^{O\text{-}C\text{-}F}Rn^{O\text{-}C\text{-}F}$

TN, tooth number; R, root; O, orifice; C, canal; F, foramen

4. Discussion

Adverse endodontic treatment outcomes may be observed due to missed root anatomy and the presence of untreated canals.[19] Achieving the goals of endodontic treatment, namely thorough cleaning, shaping and obturation of the entire root canal system are required for a favorable endodontic outcome.[20] The treatment of M1Ms is no exception, and it is well-known that the mesiobuccal root of this tooth type may frequently present with additional canals and complex internal morphology.[3,21]

Over the years, numerous methods have been used to study root canal morphology by means of both *in vitro* and *in vivo* study designs.[22-24] In the past, *ex vivo* studies often required the employment of destructive methods for the evaluation of root and canal morphology using extracted teeth, such as tooth sectioning in combination with radiography or clearing & staining.[22,23] These older methods already found a high prevalence of additional canals (> 90%) in the mesiobuccal root of maxillary first molars.[7] More recently, non-destructive imaging methods such as CBCT for clinical studies [21,25] and micro-CT for laboratory studies [26] have become increasingly common methods for the evaluation of dental morphology.[27] CBCT has been proven to be both highly accurate and reliable when used for the study of root and canal morphology.[28] CBCT has been reported to be equal or superior to

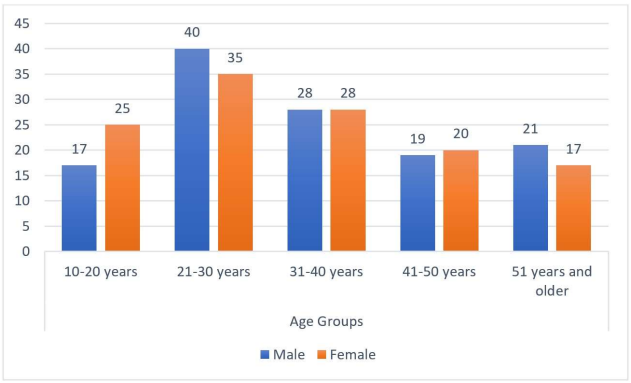

Fig 6. Distribution of age groups according to gender

Table 2. Root numbers and morphologies of the upper first molars and their mesiobuccal canals by age and sex

Variables	Total	Gender			Age Groups					p value
		Male	Female	p value	10-20 years	21-30 years	31-40 years	41-50 years	51 years and older	
Right Root Number										
One	1 (0.4%)	0 (0.0%)	1 (100.0%)		0 (0.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	
Three	244 (97.6%)	121 (49.6%)	123 (50.4%)	0.367	40 (16.4%)	74 (30.3%)	54 (22.1%)	39 (16.0%)	37 (15.2%)	0.707
Four	5 (2.0%)	4 (80.0%)	1 (20.0%)		2 (40.0%)	1 (20.0%)	1 (20.0%)	0 (0.0%)	1 (20.0%)	
Left Root Number										
One	3 (1.2%)	1 (33.3%)	2 (66.7%)		0 (0.0%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	0 (0.0%)	
Two	3 (1.2%)	2 (66.7%)	1 (33.7%)		0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (100.0%)	0 (0.0%)	
Three	239 (95.6%)	117 (49.0%)	122 (51.0%)	0.069	40 (16.7%)	72 (30.1%)	55 (23.0%)	35 (14.6%)	37 (15.5%)	0.078
Four	5 (2.0%)	5 (100.0%)	0 (0.0%)		2 (40.0%)	2 (40.0%)	0 (0.0%)	0 (0.0%)	1 (20.0%)	
Right Vertucci Classification										
Type I	96 (38.4%)	43 (44.8%)	53 (55.2%)		18 (18.75%)	22 (22.9%)	20 (20.8%)	20 (20.8%)	16 (16.7%)	
Type II	15 (6.0%)	12 (80.0%)	3 (20.0%)		1 (6.7%)	3 (20.0%)	3 (20.0%)	4 (26.7%)	4 (26.7%)	
Type III	10 (4.0%)	5 (50.0%)	5 (50.0%)		3 (30.0%)	3 (30.0%)	1 (10.0%)	0 (0.0%)	3 (30.0%)	
Type IV	61 (24.4%)	35 (57.4%)	26 (42.6%)		11 (18.0%)	23 (37.7%)	13 (21.3%)	7 (11.5%)	7 (11.5%)	
Type V	41 (16.4%)	16 (39.0%)	25 (61.0%)	0.06	6 (14.6%)	17 (41.5%)	10 (24.4%)	3 (7.3%)	5 (12.2%)	0.601
Type VI	17 (6.8%)	10 (58.8%)	7 (41.2%)		2 (11.8%)	4 (23.5%)	6 (35.3%)	3 (17.6%)	2 (11.8%)	
Type VII	6 (2.4%)	1 (16.7%)	5 (83.3%)		0 (0.0%)	1 (16.7%)	2 (33.3%)	2 (33.3%)	1 (16.7%)	
Type VIII	1 (0.4%)	1 (100.0%)	0 (0.0%)		0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Other	3 (1.2%)	2 (66.7%)	1 (33.3%)		1 (33.3%)	1 (33.3%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	
Left Vertucci Classification										
Type I	108 (43.2%)	48 (44.4%)	60 (55.6%)		18 (16.7%)	27 (25.0%)	21 (19.4%)	24 (22,2%)	18 (16.7%)	
Type II	10 (4.0%)	4 (40.0%)	6 (60.0%)		2 (20.0%)	2 (20.0%)	3 (30.0%)	1 (10.0%)	2 (20.0%)	
Type III	3 (1.2%)	1 (33.3%)	2 (66.7%)		2 (66.7%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Type IV	65 (26.0%)	39 (60.0%)	26 (40.0%)		8 (12.3%)	28 (43.1%)	15 (23.1%)	8 (12.3%)	6 (9.2%)	
Type V	36 (14.4%)	17 (47.2%)	19 (52.8%)	0.314	4 (11.1%)	12 (33.3%)	10 (27.8%)	3 (8.3%)	7 (19.4%)	0.294
Type VI	18 (7.2%)	10 (55.6%)	8 (44.4%)		4 (22.2%)	4 (22.2%)	5 (27.8%)	2 (11.1%)	3 (16.7%)	
Type VII	6 (2.4%)	5 (83.3%)	1 (16.7%)		2 (33.3%)	1 (16.7%)	1 (16.7%)	0 (0.0%)	2 (33.3%)	
Type VIII	1 (0.4%)	0 (0.0%)	1 (100.0%)		0 (0.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	
Other	3 (1.2%)	1 (33.3%)	2 (66.7%)		2 (66.7%)	0 (0.0%)	0 (0.0%)	1 (33.3%)	0 (0.0%)	
Right Ahmed et al. Classification										
^{3}16 MB^{1}	94 (37.6%)	41 (43.6%)	53 (56.4%)		17 (18.1%)	22 (23.4%)	20 (21.3%)	20 (21.3%)	15 (16.0%)	
^{3}16 MB$^{2-1}$	15 (6.0%)	12 (80.0%)	3 (20.0%)		1 (6.7%)	3 (20.0%)	3 (20.0%)	4 (26.7%)	4 (26.7%)	
^{3}16 MB^{1-2-1}	10 (4.0%)	5 (50.0%)	5 (50.0%)		3 (30.0%)	3 (30.0%)	1 (10.0%)	0 (0.0%)	3 (30.0%)	
^{3}16 MB^{2}	61 (24.4%)	35 (57.4%)	26 (42.6%)		11 (18.0%)	23 (37.7%)	13 (21.3%)	7 (11.5%)	7 (11.5%)	
^{3}16 MB$^{1-2}$	41 (16.4%)	16 (39.0%)	25 (61.0%)		6 (14.6%)	17 (41.5%)	10 (24.4%)	3 (7.3%)	5 (12.2%)	
^{3}16 MB^{2-1-2}	17 (6.8%)	10 (58.8%)	7 (41.2%)		2 (11.8%)	4 (23.5%)	6 (35.3%)	3 (17.6%)	2 (11.8%)	
^{3}16 MB$^{1-2-1-2}$	5 (2.0%)	1 (20.0%)	4 (80.0%)	0.052	0 (0.0%)	1 (20.0%)	1 (20.0%)	2 (40.0%)	1 (16.7%)	0.621
^{3}16 MB^{3}	1 (0.4%)	1 (100.0%)	0 (0.0%)		0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
16 (RF^{7})^{4} MB$_{1}^{1}$ MB$_{2}^{1}$	4 (0.4%)	3 (75.0%)	1 (25.0%)		1 (25.0%)	1 (25.0%)	1 (25.0%)	0 (0.0%)	1 (25.0%)	
^{1}16 MB$^{1-2-1-2}$	1 (0.4%)	0 (0.0%)	1 (100.0%)		0 (0.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	
16 (CsC^{1})^{4}M//D//P	1 (0.4%)	1 (100.0%)	0 (0.0%)		1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Left Ahmed et al. Classification										
^{3}26 MB^{1}	103 (41.2%)	45 (43.7%)	58 (56.3%)		17 (16.5%)	25 (24.3%)	20 (19.4%)	23 (22,3%)	18 (17.5%)	
^{3}26 MB$^{2-1}$	11 (4.4%)	4 (36.4%)	7 (63.6%)		2 (18.2%)	2 (18.2%)	3 (27.3%)	2 (18.2%)	2 (18.2%)	
^{3}26 MB^{1-2-1}	3 (1.2%)	1 (33.3%)	2 (66.7%)		2 (66.7%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
^{3}26 MB^{2}	63 (25.2%)	37 (58.7%)	26 (41.3%)		8 (12.7%)	27 (42.9%)	15 (23.8%)	8 (12.7%)	5 (7.9%)	
^{3}26 MB$^{1-2}$	35 (14.0%)	17 (48.6%)	18 (51.4%)		4 (11.4%)	12 (34.3%)	10 (28.6%)	2 (5.7%)	7 (20.0%)	
^{3}26 MB^{2-1-2}	18 (7.2%)	10 (55.6%)	8 (44.4%)		4 (22.2%)	4 (22.2%)	5 (27.8%)	2 (11.1%)	3 (16.7%)	
^{3}26 MB$^{1-2-1-2}$	6 (2.4%)	5 (83.3%)	1 (16.7%)		2 (33.3%)	1 (16.7%)	1 (16.7%)	0 (0.0%)	2 (33.3%)	
^{3}26 MB$^{2-1-2-3-2}$	1 (0.4%)	0 (0.0%)	1 (100.0%)	0.167	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0.385
^{3}26 MB^{1-2-3}	1 (0.4%)	0 (0.0%)	1 (100.0%)		1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
26 (RF^{6})^{3}MB^{1}	1 (0.4%)	0 (0.0%)	1 (100.0%)		1 (25.0%)	1 (25.0%)	1 (25.0%)	0 (0.0%)	1 (25.0%)	
26 (RF^{7})^{4} MB$_{1}^{1}$ MB$_{2}^{-1}$	3 (1.2%)	3 (100.0%)	0 (0.0%)		1 (33.3%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	1 (33.3%)	
^{1}26 MB^{1}	3 (1.2%)	1 (33.3%)	2 (66.7%)		0 (0.0%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	0 (0.0%)	
26 (CsC^{1})^{4}M//D//P	2 (0.8%)	2 (100.0%)	0 (0.0%)		1 (50.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	

MB: Mesiobuccal; RF: Root fusion; CsC: C-shaped canal

phosphor plate radiography [30] and not significantly different from micro-CT [31] for the determination of dental morphology.[32,33]

The presence of additional canals in the MB root of M1Ms has been well established by numerous studies.[7,21,26,28] The reported prevalence of additional anatomy/canals in these teeth using CBCT may however vary significantly, and has been reported to range from as low as 48% (in a Venezuelan population) to as high as 97.6 (in a Belgian population) in a worldwide CBCT study.[28] While some authors are in agreement with these findings, for example, Fernandes et al. [21] reported a high prevalence of MB2 canals (87% and 92% for left and right maxillary first molars respectively) using CBCT. Others, Silva, et al. [34], have found a much lower prevalence of MB2 canals ranging from 34 to 42% using the same methodology. This variation in the prevalence of MB2s between studies may be related to several factors, including: racial and/or ethnic differences, environmental factors, human genetics and ethnic considerations.[10,35] Furthermore, differing CBCT machines and software used by different investigators may additionally have played a role in the varied findings.[21]

The present study found no significant differences between the canal morphology of the MB root of M1Ms and the variables of sex or age. This is supported by the findings of other studies.[21,36] Other authors have found significant associations between the prevalence of MB2 canals and sex.[7,37] In several investigations, age has also been associated with the prevalence of MB2 canals in maxillary first molars, with increasing age showing a reduced prevalence of this feature.[7,37] One explanation for this finding may be the structural changes to dental tissues over time, such as the continued deposition of secondary dentin causing alteration to the pulp space and canal structure.[38] Despite this finding, it should be noted that MB2 canals and/or additional anatomy in the MB root may be observed at any age.[21] Furthermore, a high level of bilateral symmetry regarding MB2 prevalence (88-97%) has been reported in the literature.[21,36,37]

The classification systems of both Vertucci and Ahmed et al. were employed in the present study.[8,23] The well-known Vertucci classification has been used for the study of root canal morphology for several decades.[23] Advantages of the Vertucci classification system include its familiarity, simplicity and ease of use. However the system demonstrates several notable drawbacks, such as an inability to describe root number, report highly complex canal structures and dental anomalies.[8] These drawbacks are supported by the findings of the present study as well as previous studies [24,26,39], which have reported that some teeth cannot be adequately described using the Vertucci system and were simply noted as "other" or not classified.

The Ahmed et al.[8] system was recently introduced aiming to overcome some of the shortcomings of the well known Vertucci classification system and has the advantage of simultaneously providing an accurate description of both the root and canal structures found in any tooth type using a single code. This system can additionally describe complex canal configurations, anatomical variations and dental anomalies.[40] Whilst this is a notable advantage of the newer system, only a low number of dental anomalies, such as root fusion and C-shaped canals were observed in the present study. The system of Ahmed, et al. [8] could however report these complex morphologies. Although the new classification system has proven to be highly descriptive and accurate, it has the limitation that it generates a larger number of unique codes/categories compared to previous classifications, which complicates it. [24] This finding is supported by the results of the present study.

Several limitations in this study warrant attention. Given that the research was carried out in just one location, a larger sample size would have been more appropriate. Moreover, this retrospective study utilized scans with varying voxel sizes and fields, potentially influencing the outcomes. To get a more accurate gauge of this distribution in the Turkish population, multi-center studies with expanded sample sizes would be beneficial. Furthermore, the CBCT used in this study offers a lower spatial resolution compared to micro- and nano-CT, which might have affected the results.

The new classification system can be an essential tool for both undergraduate and graduate students to gain an in-depth understanding of root and canal morphology. Utilized in pre-clinical courses, this system can enhance the theoretical knowledge of students and also contribute to the improvement of their practical skills in clinical applications. Hence, the integration of this technology into the curriculum should be recognized and supported as part of innovative pedagogical approaches in dental education. Such integration can enable students to grasp complex topics like root and canal morphology more effectively, thereby enhancing the quality of education in the field of dentistry.

5. Conclusion

In conclusion, the presence of additional anatomy in the MB root of M1Ms carries important clinical significance in endodontics. Failure to locate and treat all anatomy present in a given tooth, especially MB2 canals in maxillary first molars, may result in endodontic treatment failure due to persistent microbial contamination and infection. Clinicians should therefore be aware of both the presence and prevalence of additional canals in the MB roots of M1Ms in different populations. For clinicians seeking clarity in root and canal morphology, the new classification system offers a more precise and user-friendly approach than the traditional Vertucci classification. This advancement ensures more accurate diagnosis and treatment planning, ultimately enhancing patient outcomes.

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CRediT Author Statement

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Conflict of Interest

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Original Article

Comparison of the Long Term Clinical Performances of Repaired versus Replaced Resin-Based Composite Dental Restorations: A Meta-Analysis of Clinical Trials

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CLINICAL SIGNIFICANCE

Healthcare professionals may opt to perform repairs on composite resins instead of completely replacing them. It has been noted that the efficacy of long-term clinical outcomes is comparable between the two options.

ABSTRACT

Objectives: When a composite resin restoration partially fails, dentists face the decision of replacing the entire restoration or repairing the affected area. This study aims to compare clinical outcomes between repairing and replacing dental composites through a meta-analysis of randomised clinical trials.

Materials and Methods: In June 2023, an extensive search across multiple databases (PubMed, Web of Science, Scopus, Cochrane Library, Open Grey) was conducted, focusing on marginal adaptation, anatomy, secondary caries, and colour of composite restorations. United States Public Health Service criteria-derived Alpha scores were examined, and odds ratios along with 95% confidence intervals were employed for comparisons. Data analysis was executed using Cochrane's RevMan 5.4.1 software (The Nordic Cochrane Centre, Copenhagen, Denmark).

Results: Only two studies met the eligibility criteria and were included in the analysis. Both studies were deemed to have a high risk of bias. Notably, no statistically significant differences emerged between the groups undergoing repair or replacement of composite restorations in terms of marginal adaptation (OR=0.50, 95% CI: 0.06, 3.96; p=0.51), anatomy (OR=0.69, 95% CI: 0.28, 1.68; p=0.42), and secondary caries (OR=0.47, 95% CI: 0.09, 2.54; p=0.38). However, the replacement group exhibited a higher OR when it came to colour (OR=0.19, 95% CI: 0.06, 0.65; p=0.008).

Conclusion: Both repairing and replacing dental composites exhibit comparable clinical outcomes for marginal adaptation, secondary caries, and anatomy. However, replacement offers improved colour stability in long-term assessments. Nevertheless, due to study limitations, further research is essential to comprehensively ascertain the benefits of both approaches.

1. Introduction

Over the last three decades, there has been a noticeable rise in the use of dental composites for the treatment of dental caries and the restoration of posterior teeth.[1] These materials have become a preferred alternative to amalgams.[2,3] However, it should be noted that resin-based composite materials have a relatively shorter lifespan than amalgams and are more susceptible to failure due to recurrent caries, discoloration, and deterioration.[4]

When a partial restoration of composite resin fails due to secondary caries, fractures, or other factors, selecting the optimal approach to address the localized defect becomes crucial. Dentists can choose between fully replacing the restoration or repairing the specific affected area. While some may opt for replacement, repairing the restoration can be a more beneficial option.[5] Repairing the restoration preserves healthy tooth structure and minimizes any negative effects on tooth longevity that may arise from enlarging the preparation area during full replacement. Additionally, repairing the restoration saves time and can prevent potential harm to the dentine-pulp complex that may occur during a larger repair.[6]

When faced with a flawed composite restoration, the decision to either replace or repair it rests largely on the clinician's judgment. This choice is often based on the knowledge and skillset, as well as clinician's clinical experience and expertise.[7] In contemporary dental practice, there is a growing inclination towards less invasive procedures. Consequently, dental institutions worldwide have integrated the teaching of restorative repair techniques into their curriculum, during preclinical and/or clinical years.[8]

Several clinical studies have examined the clinical performance performance of dental composites based on United States Public Health Service (USPHS) criteria, comparing repair versus replacement. Therefore, this study aims to conduct a meta-analysis of randomized clinical trials to qualify and quantify the evidence regarding clinical outcomes between repairing and replacing dental composites.

2. Materials and Methods

2.1. Guidance and eligibility criteria

This meta-analysis was performed according to the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[9] A well-defined review question was developed by using the patient population, intervention, comparison, outcome and study design (PICOS) frame-work. The following PICO framework was developed for a systematic review of the existing literature regarding the repair or replacement of damaged composite restorations:

Population (P): Patients who have restorations with localized, marginal, anatomical deficiencies, and/or secondary caries adjacent to composite resin restorations
Intervention (Cases) (I): Repair
Comparison (Control) (C): Replacement
Outcome (O): Marginal adaptation, surface roughness, secondary caries, marginal stain, teeth sensitivity, anatomic form, and luster
Study design (S): Clinical or Randomized Clinical Trials

"In patients with restorations featuring localized, marginal, anatomical deficiencies, and/or secondary caries adjacent to

composite resin restorations (P), does repair (I) compared to replacement (C) result in comparable or different outcomes in terms of marginal adaptation, surface roughness, secondary caries, marginal stain, teeth sensitivity, anatomic form, and luster (O), based on clinical or Randomized Clinical Trials (S)?"

The following types of studies were considered: firstly, the study had to investigate the effect of repair versus replacement on the longevity of composite restorations; secondly, only studies analysing resin-based composite restorations were included. Furthermore, adherence to the USPHS criteria for restoration assessment was obligatory, and lastly, the study design had to be a clinical trial.

Exclusion criteria included the following:
1. Studies that lacked a comparison between repair and replacement.
2. Studies that did not evaluate resin based-composite restorations.
3. Studies which combined amalgam and composite samples
4. Studies that examined restorations using methods other than United States Public Health Service (USPHS) criteria.
5. Studies that had an unavailable full text.
6. Short communication, review, case report, or case series.
7. Studies published in a language other than English.
There were no limitations imposed on the type of restoration, publication date, ethnicity, gender, or age.

2.2. Information sources and search strategy

In June 2023, an examiner (M.U) conducted a thorough search across multiple electronic databases, including PubMed, Web of Science, Scopus, Cochrane Library, and Open Grey. The search strategy employed a combination of Mesh terms such as "Composite Resins" and free-text terms like "Composites," "Repair," "Longevity," "Durability," and "Minimal Invasive Treatment." The specific search methodology is outlined in Table 1. Additionally, to ensure a comprehensive approach, two researchers (J.F.B.M, F.P.H) meticulously examined the reference lists of all retrieved papers to identify any further relevant studies.

Table 1. Search strategies in information sources

Database	Search strategy
PubMed	(((Composite Resin[Title]) OR (Composite[Title])) AND ((Repair[Title]) OR (Longevity[Title]) OR (Durability[Title]) OR (Replacement[Title])))
Web of Science	TI=((Composite Resin OR Composite) AND (Repair OR Longevity OR Durability OR Replacement))
Scopus	TITLE(composite) AND TITLE(repair) OR TITLE(longevity) OR TITLE(durability) OR TITLE(replacement)
Cochrane Library	#1 ("composite resin"):ti,ab,kw AND (repair):ti,ab,kw #2 ("Composite") AND ("Repair")
Open Grey	((Composite Resin) OR (composite)) AND ((Repair) OR (Longevity) OR (Durability) OR (Replacement))

2.3. Study selection and data collection process

Following the application of predetermined inclusion and exclusion criteria, two independent reviewers (J.F.B.M and F.P.H) conducted the selection of relevant articles. To ensure accuracy, reference management software (EndNote® X9 Thomson Reuters, Philadelphia, PA, USA) was utilized to identify and eliminate any duplicate entries. Efforts also included contacting the corresponding author(s) if any additional information was required from the text. The reviewers (J.F.B.M and F.P.H) agreed upon the final selection of candidate studies. From each selected study, the following information was extracted: (1) publication details (journal, title, authors, date, and country), (2) sample characteristics (ethnicity, sample size, age, and gender of the participants), (3) repair-related features (repairing technique, materials used for repair, and the protocols followed), and (4) qualitative and quantitative results.

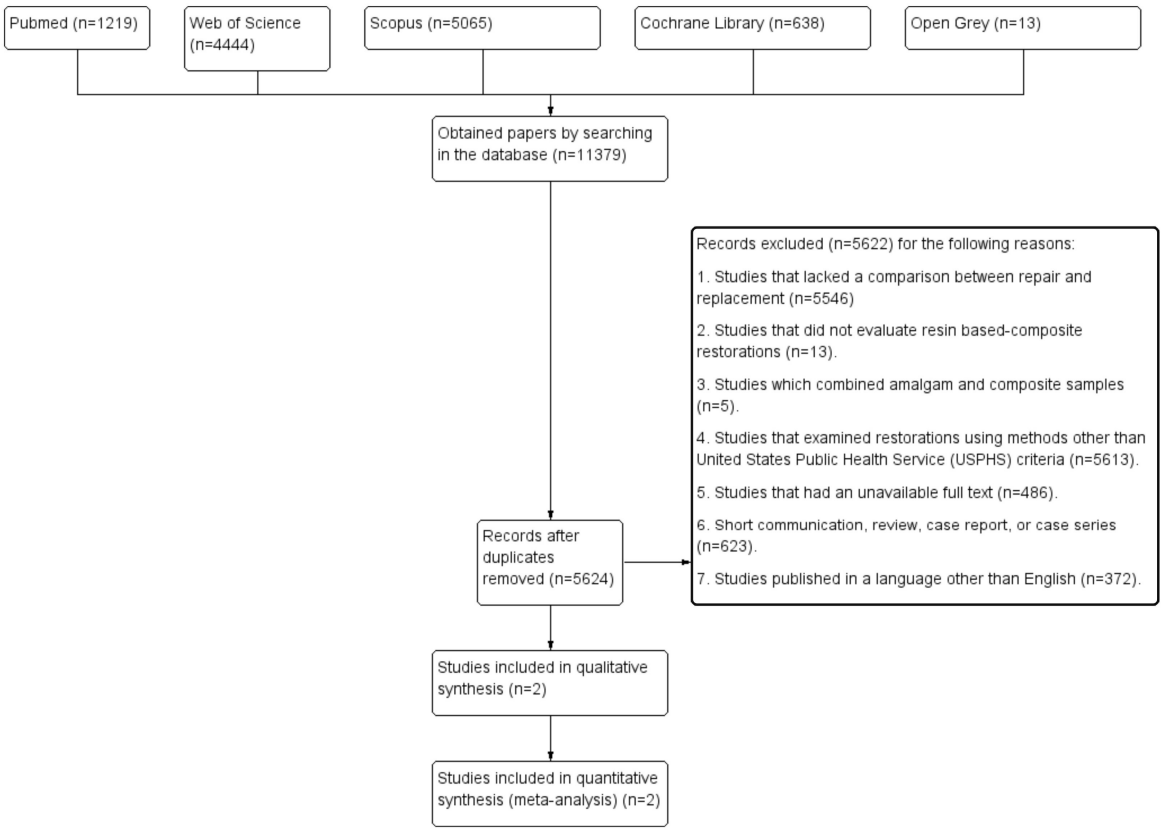

Fig 1. Flow diagram of the studies involved in the qualitative and quantitative analyses

2.4. Risk of bias within studies

To assess the risk of bias of individual studies, the revised Joanna Briggs Institute (JBI) critical appraisal tool for randomized controlled trials was used.[10] The assessment was carried out independently by two reviewers (*.*., *.*.). The risk of bias was evaluated based on the Joanna Briggs guidelines scoring system and cutoff points. Studies that scored below 49% were considered to have a "high risk of bias," those scoring between 50 to 69% were considered to have a "moderate risk of bias," and those scoring over 70% were considered to have a "low risk of bias" (based on questions 1 to 10, as recommended by Barker, et al. [10])

2.5. Summary measures

The study focused on marginal adaptation, anatomy, secondary caries, and colour as the primary outcome parameters of interest. The prevalence of alpha scores based on modified USPHS criteria was taken into account. For the purpose of contrasting the impact of repair and replacement, the odds ratio (OR) along with its corresponding 95% confidence intervals (95% CI) were employed, given that the primary outcome had a dichotomous nature.

2.6. Synthesis of results

To calculate the overall estimated effects and produce forest plots, the meta-analysis software of the Cochrane Collaboration (RevMan 5.4.1, The Nordic Cochrane Centre, Copenhagen, Denmark) was used. Methodological heterogeneity was assessed according to variability in risk of bias within the study and study design, while clinical heterogeneity was evaluated by comparing discrepancies among cases, controls, and study outcomes. The Chi-squared, Tau-squared, and Higgins I^2 tests were used to assess statistical heterogeneity. Heterogeneity was classified based on I^2 test results: <30% not significant; 30%-50% moderate; 50%-75% substantial, and 75%-100% considerable.[11] Even if statistical homogeneity was obtained, the random-effects model was preferred with 95% confidence intervals as the meta-analysis model due to a lack of clinical and methodological homogeneity.[12] In all tests, a random-effects model was used, and the level of significance was set at $p < 0.05$.

2.7. Risk of Bias Across Studies

A funnel plot analysis could not be performed due to the inclusion of fewer than 10 studies.

2.8. Grade Analysis

The Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) system was employed to assess evidence quality and establish recommendation strength. This involved generating a Summary of Findings (SoF) table through GRADEpro GDT, an online software developed by the GRADE Working Group.[13]

3. Results

3.1. Study Selection

A total of 11379 records (1219 from Pubmed, 4444 from Web of Science, 5065 from Scopus, 638 from Cochrane Library, and 13 from Open Grey) were obtained. Following duplicate removal, the number of studies was reduced to 5,624. From this pool, only 2 clinical studies[14,15] satisfied the eligibility criteria and were included in the qualitative and quantitative syntheses (Fig 1).

3.2.Characteristics of the included studies

Both studies were clinical trials with sample sizes of 28 (12 male, 16 female)[14] and 34 (14 male, 20 female)[15] subjects. Participants' ages spanned from 18 to 80 years in both trials. The follow-up periods were 10 years [14] and 12 years [15]. Filtek Supreme and Adper Prompt L-Pop, both by 3M ESPE in the USA, served as the composite resin and bonding materials across both studies.

3.3. Risk of bias within the studies

Both studies were classified as possessing a high risk of bias. These biases were primarily linked to aspects such as selection and allocation, assessment, and participant retention, as outlined in Table 2.

3.4. Results of individual studies

At follow-up, all groups exhibited marginal adaptation scores below 50%. Notably, only the replacement group achieved an anatomy score exceeding 50% in Fernandez, et al. [14]. Conversely, in the study of Estay, et al. [15], the anatomy scores remained below 50%. Estay, et al. [15] assessed roughness and recorded scores of 7% for repair and 46% for replacement groups. Concerning colour,

Table 2. The revised Joanna Briggs Institute (JBI) critical appraisal tool for randomized controlled trials that was used to assess the risk of bias in individual studies.

			INTERNAL VALIDITY												
			Bias related to: Selection and Allocation, Assessment, and Participant retention												
		Domain	Selection and Allocation			Administration of intervention/exposure			Assessment, detection, and measurement of the outcome			Participant retention	Statistical Conclusion Validity		
		Question	1	2	3	4	5	6	7	8	9	10	11	12	13
STUDY ID	OUTCOME	RESULT													
Fernandez, et al. [1]	MA	Repair	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	MA	Replacement	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	AN	Repair	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	AN	Replacement	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	SC	Repair	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	SC	Replacement	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	CO	Repair	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	CO	Replacement	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
Estay, et al. [2]	MA	Repair	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	MA	Replacement	Y	U	N	N/A	N/A	N/A	U	Y	Y	Y	N	Y	N/A
	AN	Repair	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	AN	Replacement	Y	U	N	N/A	N/A	N/A	U	Y	Y	Y	N	Y	N/A
	SC	Repair	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	SC	Replacement	Y	U	N	N/A	N/A	N/A	U	Y	Y	Y	N	Y	N/A
	CO	Repair	Y	U	N	N/A	N/A	N/A	U	Y	Y	N	N	Y	N/A
	CO	Replacement	Y	U	N	N/A	N/A	N/A	U	Y	Y	Y	N	Y	N/A

MA: Marginal Adaptation, AN: Anatomy, SC: Secondary Caries, CO: Colour, Y: Yes, N: No, U: Unclear, N/A: Not Applicable

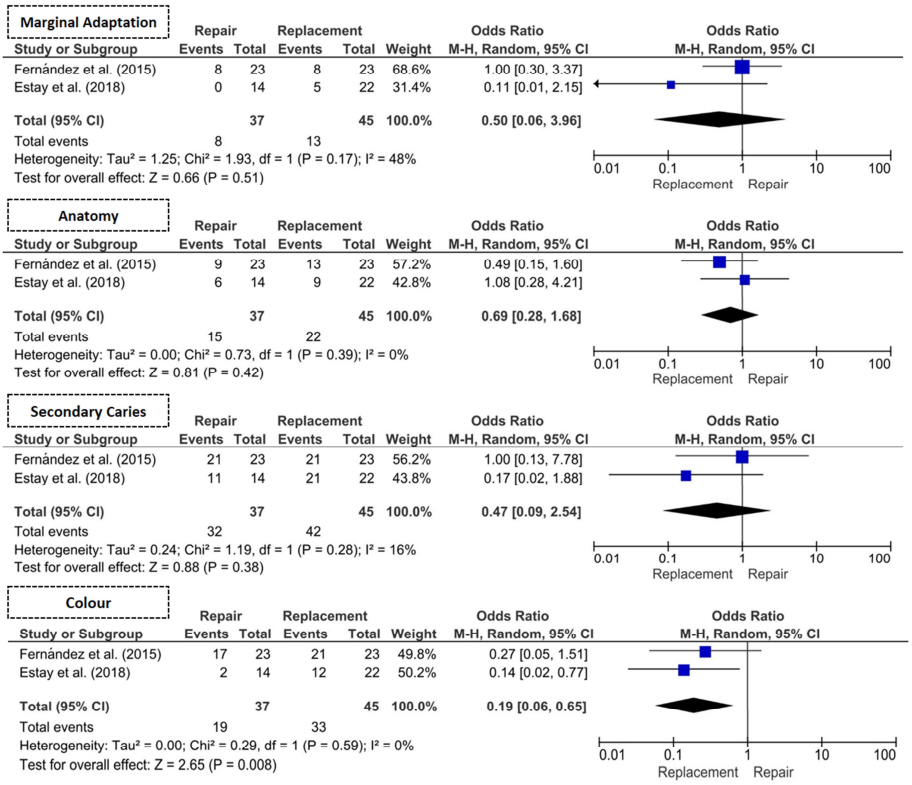

Fig 2. Forest plot presentations of all outcomes

replacement showed scores of 92%[14] and 55%[15], while repair attained 75%[14] and %13[15] in the respective studies. Tooth sensitivity was only evaluated by Estay, et al. [15] and it was found to be 100% in both repair and replacement. For secondary caries, all groups had more than 80% alpha scores. Luster was only evaluated by Estay, et al. [15] and scores of 13% and 41% were recorded in the repair and replacement groups, respectively (Table 3).

3.5. Synthesis of results

The current meta-analysis did not find any significant difference between the groups that underwent repair versus replacement in terms of marginal adaptation (OR=0.50, 95% CI: 0.06, 3.96; p=0.51), anatomy (OR=0.69, 95% CI: 0.28, 1.68; p=0.42), and secondary caries (OR=0.47, 95% CI: 0.09, 2.54; p=0.38). However, the replacement group showed a higher OR in terms of colour (OR=0.19, 95% CI: 0.06, 0.65; p=0.008) (Fig 2).

No significant heterogeneity was observed for the outcomes of anatomy (Tau^2=0.00, Chi^2=0.73, I^2=0%, p=0.39), secondary caries (Tau^2=0.24, Chi^2=1.19, I^2=16%, p=0.28), and colour (Tau^2=0.00, Chi^2=0.29, I^2=0%, p=0.59). Moderate heterogenity was found for marginal adaptation (Tau^2=1.25, Chi^2=1.93, I^2=48%, p=0.17). While there was no notable heterogeneity within the studies, the use of a random effects model was needed in all quantitative analyses due to methodological heterogeneity arising from differing follow-up periods (Fig 2).

3.6. Grade Analysis

The GRADE approach initially regards clinical studies as high-quality evidence. However, the quality of evidence may be diminished by five factors: risk of bias, inconsistency, indirectness, imprecision, and publication bias. Conversely, three factors - large effect, dose-response, and all plausible confounding - may enhance evidence quality. Regrettably, the studies included were characterized by a high risk of bias, resulting in a low rating for all outcomes. Consequently, the confidence level in the cumulative evidence assessment based on GRADE criteria was categorized as low for all outcomes (Fig 3).

4. Discussion

Minimal intervention procedures suggested by researchers, such as restoration repair, can be an effective method to prevent the unnecessary removal of healthy tooth structure.[5] This approach aligns with the minimally invasive principles and can significantly help in preserving the natural tooth structure. These treatments can not only extend the lifespan of the restored teeth, but also prevent the need for more invasive procedures in the future.[6] By opting for these alternative treatments, patients can experience a more conservative approach to dental care while maintaining optimal oral health.

It has been observed that many general practitioners spend a considerable amount of their productive time replacing restorations, which often leads to a "re-restoration cycle." This cycle can be detrimental to the overall health of the tooth as it leads to larger restorations and an increase in the surface area of the restorations.[16] Furthermore, complete replacement of the restoration may cause potential pulp and dentin reaction to thermal. chemical. bacterial. or mechanical stimuli. This reaction

Table 3. Results of individual studies included in the qualitative synthesis (n=2)

Study	Group	Initial Sample size	Lost to follow-up	Frequency of alpha scores in the following period						
				MA	A	R	CO	S	SC	L
Fernandez, et al.	Repair	25	2	36%	40%	-	75%	-	93%	-
	Replacement	25	2	35%	57%	-	92%	-	93%	-
Estay, et al.	Repair	15	1	0%	27%	7%	13%	100%	80%	13%
	Replacement	22	-	23%	41%	46%	55%	100%	96%	41%

MA: Marginal adaptation, A: Anatomy, R: Roughness, CO: Colour, S: Sensitivity, SC: Secondary Caries, L: Luster

Outcomes	Anticipated absolute effects* (95% CI) Risk with Replacement	Risk with Repair	Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)	Comments
Marginal adaptation (MA) assessed with: Alpha Score follow-up: mean 11 years	29 per 100	**17 per 100** (2 to 62)	**OR 0.50** (0.06 to 3.96)	82 (2 RCTs)	⊕⊕◯◯ Low[a]	Repair may result in little to no difference in marginal adaptation.
Anatomy (AN) assessed with: Alpha Scores follow-up: mean 11 years	49 per 100	**40 per 100** (21 to 62)	**OR 0.69** (0.28 to 1.68)	82 (2 RCTs)	⊕⊕◯◯ Low[a]	Repair may result in little to no difference in anatomy.
Secondary Caries (SC) assessed with: Alpha Scores follow-up: mean 11 years	93 per 100	**87 per 100** (56 to 97)	**OR 0.47** (0.09 to 2.54)	82 (2 RCTs)	⊕⊕◯◯ Low[a]	Repair may result in little to no difference in secondary Caries.
Colour (CO) assessed with: Alpha Scores follow-up: mean 11 years	73 per 100	**34 per 100** (14 to 64)	**OR 0.19** (0.06 to 0.65)	82 (2 RCTs)	⊕⊕◯◯ Low[a]	Repair may result in a reduction in colour.

a. Most information is from studies with high risk of bias

Fig 3. Summary of Findings table

can result in additional stress on the tooth, depending on the size and depth of the existing restoration.[17] It is important to consider the potential consequences of restoration replacement before proceeding with any such procedure.

Resin composite materials have made significant progress, but they still have some drawbacks. Composite restorations can fail due to various reasons such as secondary caries, fracture, marginal deterioration, discolouration, abrasion, and marginal clearance.[18] Quality criteria for clinical acceptability are defined using different scales, and composite restorations are considered defective if they have secondary caries, chipping, or fracture of the restoration or tooth, or if there are marginal defects, such as gaps between the tooth surface and the restoration.[1]

One of the main reasons why restorations may need to be replaced is due to secondary caries. However, if this issue is detected early on, there is a greater chance of successfully treating the problem.[19] In addition, repairing composite resins with inadequate occlusal or proximal anatomy can improve prognosis and correct contact issues. This meta-analysis showed that there was no significant difference in the long-term formation of secondary caries whether composite restorations were repaired or replaced.

The results of the present study show that there is no major difference in the long-term clinical outcomes of replaced or repaired composite restorations when it comes to marginal adaptation. One downside to using the USPHS criteria is that it cannot differentiate whether marginal deterioration is due to the repaired area or the original restoration when conducting a clinical assessment of marginal adaptation. However, this deterioration can be offset by performing a marginal seal simultaneously.[20] Restoration repairs can also improve the stability of composite resin margins over time. Fernandez, et al. [14] observed significant improvement in both groups after the first year, followed by similar deterioration until reaching a similar state 10 years later. Additionally, scores moved from Alpha to Bravo, indicating that the restorations remained clinically acceptable but declined in their marginal adaptation.

In the process of restoring a damaged tooth, it is essential to consider the anatomy of the composite resin employed. The proper functionality of the tooth is directly dependent on the shape and quality of the composite resin utilized. Inadequately shaped composite resins can result in complications such as food getting stuck, and insufficient contact, which can lead to further damage.[19] However, according to this meta-analysis, both repair and replacement methods have shown similar long-term anatomical success rates in clinical settings.

Over time, resin-based composite resins tend to undergo a colour change due to the softening of the resin matrix caused by water absorption.[21-23] According to this meta-analysis, replaced composites exhibit better colour stability than repaired ones. This could be due to the fact that the newly made composite is less exposed to external factors in the oral environment as the entire composite is replaced. On the other hand, the old composite structure at the border of the repaired composite may be more susceptible to discolouration.

The study exhibited certain limitations that must be taken into account. Firstly, due to the lack of available research on the subject, only two clinical studies were included in the meta-analysis. Secondly, the high heterogeneity across the studies, particularly in the duration of follow-up, was another limitation that should be acknowledged. It should be noted that a potential limitation of the study is that it solely considered research conducted in the English language, thus introducing the possibility of language bias. However, despite these limitations, the study offers substantial evidence due to its reliance on clinical studies, which stands as a notable strength of this research.

5. Conclusion

The findings of the study have shown that when it comes to marginal adaptation, secondary caries, and anatomy, both repairment and replacement procedures have similar performance. However, the replacement was observed to yield better results in terms of colour in long-term clinical evaluations. Nevertheless, it is important to consider the limitations of the study, such as the heterogeneity between the studies and the limited number of studies. Hence, the strength of evidence derived from the present study is limited. Consequently, providing a definitive clinical recommendation regarding the efficacy of the two methods being compared is difficult. It is crucial to conduct more comprehensive clinical studies to gather a more thorough understanding of the effectiveness of each method.

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CRediT Author Statement

J.F.B.M. : Investigation, Data Curation, Writing - Review & Editing, M.U. : Investigation, Data Curation, F.P. : Methodology, Formal analysis, Investigation, Writing - Original Draft, Supervision, Project administration

Conflict of Interest

The authors declare that no conflict of interest is available

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Original Article

Evaluation of the outcomes of endodontic treatment applications performed by undergraduate students during dental education

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CLINICAL SIGNIFICANCE

To improve the quality of endodontic treatment, it is crucial to place a strong emphasis on the enhancement of endodontic education during undergraduate dental training. This can be achieved through the integration of hands-on clinical experiences.

ABSTRACT

Objectives: Assessing the outcomes of endodontic treatments performed by undergraduate students is important for providing better treatments and improving the education. This study aimed to assess the radiographic outcomes of endodontic treatments performed by undergraduate students over a follow-up period of 24-52 months.

Materials and Methods: Endodontic treatments performed by undergraduate students between January 2020 and May 2021 were retrospectively evaluated. Patients who underwent root canal treatment and had at least 2 years of follow-up radiography after the initial treatment were included. The presence of lesions was recorded, and subsequent treatment procedures performed on the same tooth were also documented. The Jamovi program was used for statistical analysis.

Results: Out of 464 teeth, 104 (22.4%) were included in the study. The average time interval for patients returning for follow-up visits at the dental faculty was 35±6.79 months. Mandibular molar teeth were the most frequently treated, while mandibular anterior teeth received the least treatment. A significant decrease in PAI scores was observed for teeth treated by fourth-year students ($p<0.05$), while no significant difference was found for teeth treated by fifth-year students ($p>0.05$). Tooth extraction was the most common secondary procedure performed (12%).

Conclusion: Academic term, tooth group, and presence of crowns were identified as influential prognostic factors for endodontic treatment outcomes. Fourth-year students tend to have higher success rates than fifth-year students. This may be due to the fact that the dental cases treated in fourth year are usually less complex, mainly involving anterior and premolar teeth.

1. Introduction

If the pulp tissue sustains irreversible damage, it is necessary to undergo endodontic treatment to restore the normal physiology and chewing functions of the tooth.[1] The primary aim of endodontic treatment is to achieve satisfactory coronal restoration with proper debridement, shaping of the root canal system, and final obturation.[2] Despite the complex structure of the root canal system, research has shown that the endodontic treatment success rate ranges between 85% and 95% if the infection is confined to the pulp chamber.[1] However, there is still a chance of treatment failure due to persistent infection or recontamination of the root canal system.

Several studies have explored the various factors that affect the success of non-surgical root canal treatments. A prior research has pointed out that the periapical status is a crucial preoperative factor that significantly impacts the outcome.[3] However, other factors such as the patient's age, gender, tooth type, the occurrence of procedural errors during the treatment, follow-up period, quality of coronal restoration, and the clinician's skill also play a crucial role in determining the treatment outcome.[4-6]

After examining literature on the subject, it has been observed that root canal treatments carried out by professionals with specialized training have a higher success rate compared to those performed by undergraduate students.[7,8] Although guidelines have been put in place to improve the outcomes of endodontic treatments, studies evaluating the results of non-surgical root canal treatments by undergraduate students show success rates ranging from 61% to 81%.[9,10]

The results of endodontic treatments are one of the evaluation criteria for students to improve their quality of endodontic undergraduate education. Although the outcomes of canal treatments conducted by undergraduate students have been reported in various studies within the literature, the limitations in assessment periods, the criteria used for success assessment, sample sizes, and variables such as tooth- or root-based evaluations impact these results in different ways.[5,9,11] This study aimed to report the relationship between the results of endodontic treatment outcomes applied by undergraduate students during their educational process and various parameters such as patient's age, gender, the tooth type receiving treatment, the presence of crown, and the academic term of the student in follow-ups of 24-52 months.

2. Materials and Methods

A retrospective study was conducted in line with the ethical guidelines established by the Declaration of Helsinki principles. To guarantee compliance with these principles and ethical standards, the study received ethical approval from Recep Tayyip Erdogan University, the local Ethics Committee (Approval no: 2023/198).

2.1. Sample size calculation

To calculate effect size, G Power 3.1 software from Kiel University in Germany was utilized. By analyzing the Periapical Index (PAI) scores obtained from a study evaluating the periapical conditions of endodontically treated teeth conducted by Peker, et al. [12], a sample size of 70 participants was determined to be appropriate, with a type 1 error of 0.05 and a power of 99%.

2.2. Calibration procedure

A randomly selected 10% of the periapical status from patient records treated by students was reviewed by two experts on separate times to assess the consistency between and within

observers utilizing Kappa Statistical Analysis. The instructors did not know which students belonged to which observer.

2.3. Study design

This study retrospectively evaluated the outcomes of endodontic treatments conducted by undergraduate students in their 4th and 5th years at the Department of Endodontics, Recep Tayyip Erdogan University Faculty of Dentistry, from 2020 to 2021. The study focused on radiographic outcomes, and data such as the patient's age, gender, existing systemic diseases, the tooth type receiving treatment, and the academic term of the student performing the treatment were obtained from the university's patient information system. The teeth were divided into six groups, including anterior, premolars, and molars for both maxilla and mandibula.

If the system had no record of the patient from the time of their root canal treatment until May 2023, it was marked as "no further entries made into the system." If there was a record, we checked whether any procedures, such as extraction, retreatment, crown, apical surgery, or restoration renewal, had been performed on the treated tooth, and recorded the information accordingly. If no procedure had been carried out on a tooth that was previously treated by students, and if a new panoramic radiograph was taken, the relevant tooth was included in the radiographic evaluation.

The study included patients who did not have any underlying health conditions that could complicate their treatment, with immature permanent teeth that had high-quality diagnostic imaging available for follow-up for at least 24-52 months, and who underwent non-surgical root canal treatment, which was performed by 4th and 5th year dental students under clinical supervision. Patients under 18 years old, teeth with external/internal resorption, root fractures, intraosseous pathology, or image artifacts that prevented evaluation were excluded from the study.

2.4. Endodontic treatment protocol

All endodontic treatments were performed by undergraduate dental students under the supervision of experienced endodontic clinical staff, following the same treatment protocol. After evaluating each patient's medical and dental history, a diagnosis was made for the tooth following clinical and radiographic examinations. After obtaining informed consent from each patient, local anesthesia was administered when deemed necessary. Following cavity preparation, straight-line access was established. Using an electronic apex locator and radiography, working length was determined using #10 to #15 K-type files. The root canals were enlarged using stainless steel hand files until a #25 master apical file size was achieved. Subsequently, ProTaper Universal files (PTU; Dentsply Maillefer, Ballaigues, Switzerland) were used to shape the root canals at the working length. In cases of retreatment, ProTaper Retreatment files (Dentsply Maillefer, Ballaigues, Switzerland) were used along with a solvent if necessary, to remove gutta-percha and sealer from the canal. During shaping, root canals were irrigated using 2 ml of 2.5% sodium hypochlorite (NaOCl) between each file. In cases of teeth with apical periodontitis, if the tooth was asymptomatic and the canals were dry before the procedure, the treatment was performed in a single session. Otherwise, calcium hydroxide was used as an intracanal medicament. Two weeks later, when the teeth exhibited normal clinical signs and symptoms, root canals were irrigated with 5 mL of 17% ethylenediaminetetraacetic acid (EDTA) (Saver, Prime Dental, Maharashtra, India), 2 mL of 0.9% isotonic sodium chloride (Polifarma, Tekirdağ, Turkey), and 5 mL of 2.5% NaOCl (Microvem AF, Istanbul, Turkey).The canals were filled using the cold lateral condensation technique with gutta-percha and resin-based root canal sealer. Finally, the teeth were permanently restored either with direct composite resin or with indirect restorations.

2.5. Radiographic assessment

Two endodontists with five years of experience independently reviewed all digital images. The evaluation was conducted by a Consultant Endodontist on a voluntary basis. To ensure objectivity, the observers examined panoramic radiographs twice at a two-week interval separately. The results were compared, and a final consensus was reached. In case of discrepancies, radiographs were re-evaluated until a consensus was reached between the observers. If no consensus could be reached, the relevant data was excluded from the study.

At the same power settings (66 kVp, 8 mA, and 16.6 s exposure time), panoramic images obtained from the Planmeca Promax 2D S2 device (Planmeca, Helsinki, Finland) were evaluated. The images were positioned with the Frankfurt horizontal plane parallel to the ground and aligned with the sagittal plane with the vertical plane of the digital panoramic device. The preoperative and postoperative periapical status of the treated teeth was radiographically evaluated using the PAI as suggested by Ørstavik, et al. [13] In multi-rooted teeth with the presence of multiple apical lesions, the root with the worst PAI score among all roots was used to represent the score of the respective tooth.[14] PAI is based on the usage of reference radiographs with confirmed histological diagnoses and consists of five categories as follows [13]:

PAI 1: Normal periapical structure;
PAI 2: Small changes in bone structure;
PAI 3: Changes in bone structure along with some mineral loss;
PAI 4: Periodontitis with well-defined radiolucent areas;
PAI 5: Severe periodontitis with features of exacerbation.

2.6. Statistical analysis

For the statistical analysis, Jamovi Software (Version: 2.3.26) was utilized. A descriptive analysis was carried out, and the normality was tested using the Anderson-Darling test. As the distribution was non-normal, Wilcoxon Signed-Rank, Mann-Whitney U, and Kruskal Wallis analyses were conducted. The significance level was set at $p<0.05$.

3. Results

The inter-reliability analysis showed a good level of standardization among the observers, with a kappa value of 0.82 for PAI scores. In the intra-reliability analysis, 10% of the cases were duplicated, and the agreement percentage for PAI scores was 79%.

There were 84 patients, with 33% males (n=30) and 64% (n=54) females. The average age of the patients was 42 years old (Table 1). Out of the 464 treated teeth, 104 were followed up. Of those, 45% were followed for 36 months or more, and the remaining 55% were followed for less than 36 months. The most commonly treated teeth were mandibular molars (35%) while the least treated were mandibular anterior teeth (5.8%). 79% of procedures were root canal treatments, and 21% were retreatments. Most teeth (66%) did not require additional procedures, but the most common secondary procedure was extraction (14%). The study included teeth treated by both fourth and fifth-grade students equally (Table 2).

No significant differences were observed in post-treatment PAI scores in relation to follow-up duration, gender, and age range ($p>0.05$). However, significant differences in post-treatment PAI

Table 1. The frequencies of involved patients in the study

Characteristic	Patient N = 84
Gender	
Male	28 (33%)
Female	56 (67%)
Age	42 (25, 49)

[1] n (%), Median (IQR)

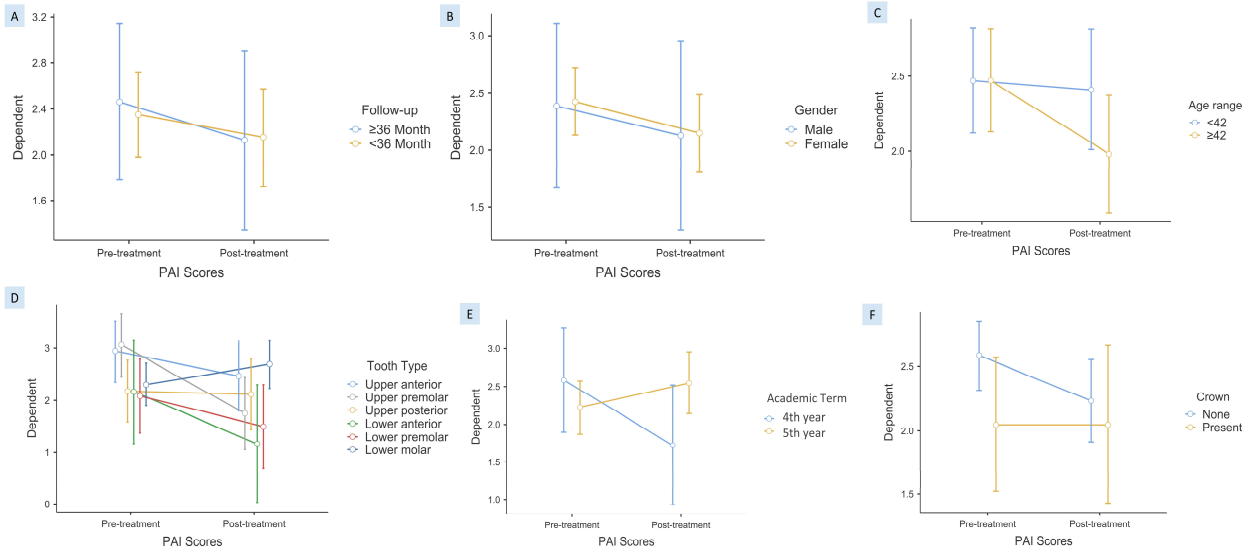

Fig. 1. The plots that show the pre and post PAI Scores according to (A) follow-up period, (B) gender, (C) age range, (D) tooth type, (E) academic term, and (F) the presence of crown.

scores were detected among tooth types ($p<0.05$), with mandibular molars and maxillary anterior teeth exhibiting higher post-treatment score. Additionally, the pre-treatment PAI scores of teeth treated by fourth-year students were significantly higher compared to those treated by fifth-year students ($p<0.05$). After treatment, the PAI scores of teeth treated by fifth-year students were significantly higher than those treated by fourth-year students ($p<0.05$) (Table 3).

There were no significant differences in pre-treatment and post-treatment PAI values concerning before and after the 36-month follow-up ($p>0.05$) (Fig. 1A). Among females, the pre-treatment PAI score was significantly higher than the post-treatment PAI score ($p<0.05$), while no significant difference was observed among males ($p>0.05$) (Fig. 1B). For age, individuals aged 42 and above displayed a significantly higher pre-treatment PAI score than the post-treatment PAI score ($p<0.05$), whereas no significant difference was found for those under 42 years ($p>0.05$) (Fig. 1C). The PAI score for maxillary premolar teeth significantly decreased ($p<0.05$), but no significant change was observed for other teeth ($p>0.05$) (Fig. 1D). Furthermore, the PAI score significantly decreased for teeth treated by fourth-grade students ($p<0.05$), but no significant difference was noted for teeth treated by fifth-grade students ($p>0.05$) (Fig. 1E). While it was observed that the PAI score decreased significantly in the crowned teeth ($p<0.05$), there was no significant difference in the non-crowned teeth ($p>0.05$) (Fig. 1F) (Table 3).

Table 2. The frequencies of involved teeth in the study

Characteristic	Teeth N = 104
Followup	
≥36	47 (45%)
<36	57 (55%)
Tooth type	
Upper anterior	17 (16%)
Upper premolar	16 (15%)
Upper posterior	17 (16%)
Lower anterior	6 (5.8%)
Lower premolar	12 (12%)
Lower molar	36 (35%)
Treatment	
Root Canal Treatment	82 (79%)
Retreatment	22 (21%)
Secondary operation	
Extraction	15 (14%)
Replacement	8 (7.7%)
Resection	2 (1.9%)
Retreatment	10 (9.6%)
None	69 (66%)
Student's grade	
4th grade	52 (50%)
5th grade	52 (50%)

[1] n (%), Median (IQR)

4. Discussion

One of the evaluation criteria for endodontic treatments performed by undergraduate students is the outcomes of these treatments.[9] In Turkey, there are few studies that focus on the long-term evaluation of endodontic treatment outcomes performed by dental students, and these studies often emphasize the impact of root canal filling quality on success.[9,12] Therefore, the purpose of this study was to assess the outcomes of non-surgical endodontic treatments completed by undergraduate students. Additionally, the study aimed to clarify the potential effects of various parameters such as age, gender, tooth type, academic term (fourth and fifth year), and periapical status on the success of

Table 3. The relationship between various factor and PAI scores

Factors	Pre-treatment PAI scores	Post-treatment PAI scores	p-value
Follow-up			
≥36	2 (1-5)	2 (1-5)	0.071[1]
<36	2 (1-5)	1 (0-5)	0.504[1]
p-value	0.253[2]	0.188[2]	
Gender			
Male	2 (1-5)	2 (0-5)	0.935[1]
Female	2 (1-5)	1 (1-5)	**0.013**[1]
p-value	0.962[2]	0.294[2]	
Age range			
<42	2 (1-5)	2 (0-5)	0.771[1]
≥42	2 (1-5)	1 (1-5)	**0.036**[1]
p-value	0.973[2]	0.163[2]	
Tooth type			
Upper anterior	3 (1-5)	2 (1-5)	0.125[1]
Upper premolar	3 (1-4)	1 (1-4)	**0.002**[1]
Upper molar	2 (1-5)	1 (1-5)	0.959[1]
Lower anterior	2 (1-3)	1 (1-2)	0.095[1]
Lower premolar	2 (1-4)	1 (1-4)	0.168[1]
Lower molar	2 (1-5)	3 (0-5)	0.235[1]
p-value	0.104[3]	**0.036**[3]	
Academic term			
4th year	2.5 (1-5)	1 (1-5)	**<0.001**[1]
5th year	2 (1-5)	2 (0-5)	0.289[1]
p-value	**0.049**[2]	**0.034**[2]	
Crown			
None	2 (1-5)	1.5 (0-5)	0.053[1]
Present	2 (1-5)	1 (1-5)	**0.038**[1]
p-value	0.062[2]	**0.048**[2]	

[1] Wilcoxon Signed-Rank test, [2] Mann-Whitney-U test, [3] Kruskal-Wallis test

endodontically treated teeth.

In many epidemiological studies, panoramic radiographs have been found to be sufficient for detecting periapical pathologies, and statistically significant differences have not been reported between panoramic and periapical radiographs.[15,16] Ahlqwist et al.[17] reported a sensitivity of 76-96% for panoramic radiographs in assessing periapical pathologies. In this study, the periapical status of endodontically treated teeth was evaluated using digital panoramic radiographs. The objective of assessing the outcome of endodontic treatment is not just to analyze a single image but to compare potential changes in periapical status between two images of the same tooth taken at different times.[18]

The PAI developed by Ørstavik, et al.[13] is the most commonly cited method in many epidemiological and clinical studies that assess the outcomes of endodontic treatment. It is based on comparing the radiographic image of periapical changes with histological analyses' results. PAI demonstrates excellent accuracy, sensitivity, validity, and repeatability among researchers.[12,18] Therefore, in the current study, the outcomes of endodontic treatments performed by undergraduate students over a period of 24-52 months were evaluated using the PAI method.

Previous studies have indicated that in cases where endodontic treatment is successful, the majority of lesions completely heal within 2 years, with only 3-5% requiring three or more years for complete "conventional radiographic healing".[19,20] A systematic review assessing treatment success have suggested adopting a follow-up period of at least 3 years instead of 2 years.[21] Therefore, in this study, a minimum follow-up period of 24 months was set, and the results were compared before and after 36 months. Teeth with follow-up radiographs between 24-36 months and 36-52 months showed no significant differences in both intra-group and inter-group pre-treatment and post-treatment PAI scores. While various studies have reported an increase in periapical healing rates with longer follow-up durations, this result supports the notion that periapical lesions exhibit substantial healing within 2 years.[22,23]

There was no significant difference between pre-treatment and post-treatment PAI scores for male and female. However, when comparing pre-treatment and post-treatment PAI scores, a significant decrease was observed in female's scores compared to pre-treatment, while no significant difference was seen in male. Epidemiological studies have generally reported that gender does not have a significant impact on endodontic treatment success.[24,25] However, in contrast to these studies, similar to the present study, Marquis, et al.[26] reported higher endodontic treatment success rates in female compared to male. While many studies examining the relationship between age and endodontic treatment success have stated that there is no significant relationship between these two parameters, Imura, et al.[7] found that age does affect endodontic treatment success and demonstrated that the success rate was higher in the 50-59 age group compared to other groups they examined.[27-29] In the current study, a significant decrease in post-treatment PAI scores compared to pre-treatment was observed in patients aged 42 and above, while no significant change in PAI scores was observed in patients aged below 42.

Due to their status as the first permanent teeth to erupt and their susceptibility to decay and pulpal diseases, various studies have shown that mandibular first molars are the most commonly treated teeth with root canal procedures in the permanent dentition.[30] Consistent with the findings of these studies, the current study observed that among all teeth, mandibular molars were the most frequently treated. However, while there was no significant difference in pre-treatment PAI scores among different tooth groups, significant differences were detected in post-treatment PAI scores. Higher PAI scores were observed post-treatment in mandibular molar teeth and maxillary anterior teeth compared to other tooth groups. Various studies examining the success of root canal treatment have indicated that mandibular molars tend to have the lowest success rates, whereas maxillary anterior teeth exhibit higher success rates.[31] This discrepancy might arise from unequal pre-treatment lesion sizes or different distributions of endodontically treated teeth among all tooth groups.[31] While there was a significant decrease in PAI scores post-treatment in maxillary premolar teeth, no significant change was observed in PAI scores for other tooth groups. In alignment with this study, Dammaschke et al.[31] reported a better prognosis for maxillary premolar teeth compared to other tooth groups, while Wiemann et al.[32] stated that premolar teeth have lower success rates than anterior teeth. These conflicting results could be attributed to variations in follow-up durations and the numerical distribution of included tooth groups in the studies.[31-33]

The pre-treatment PAI scores of teeth treated by 4th-year students were higher compared to those treated by 5th-year students. However, upon assessing post-treatment PAI values, it was found that teeth treated by 5th-year students exhibited statistically higher scores than those treated by 4th-year students. Furthermore, although there was no statistically significant difference in PAI scores for teeth treated by 5th-year students, a statistically reduction in PAI scores was observed for teeth treated by 4th-year students. This outcome may stem from the allocation of single-rooted teeth to 4th-year students, while multi-rooted teeth and more challenging cases were assigned to the more experienced 5th-year students.[9] In line with our findings, studies have highlighted that many students require more practical experience in performing molar endodontics.[34,35]

According to this study, the most commonly performed secondary procedure was tooth extraction (14%), which is similar to the extraction rates (15.3%) reported in the study by Dammaschke et al.[31] that investigated the long-term survival of endodontically treated teeth. In numerous studies, it has been reported that teeth with crowns have a higher survival rate compared to non-crowned teeth.[36,37] Similarly, with this study results, there was a significant decrease in PAI scores for teeth with crowns, supporting this claim.

This study has limitations due to its retrospective nature and lack of control over variables. Other limitations of the study include the lack of assessment of initial symptoms, the vitality of the tooth, and lesion sizes, which are important for prognosis at the beginning of treatment. The non-standardized use of rubber dams during treatment, neglect of curved roots, canal filling, and restoration quality, as well as the absence of knowledge about clinical signs and symptoms during the follow-up period, can be considered as other limitations of the study. Previous evidence regarding the impact of general health on endodontic treatment outcomes is contradictory.[38,39] In this current study, the proportion of individuals with systemic diseases was small (<20%), which precluded investigating the potential effects of overall health on endodontic treatment outcomes. Despite the limited sample size, the results of this study partially corroborate the data obtained from previous research. However, there is a scarcity of high-quality studies evaluating the outcomes of endodontic treatments performed by students. Moreover, it has been reported that the instruments and techniques used, evaluation criteria, follow-up durations, and sample sizes can significantly impact the results of studies. To more precisely determine all prognostic factors influencing the prognosis of endodontic treatment, there is a need for longer-term research with larger sample sizes and higher-quality evidence.

5. Conclusion

Within the limitations of this retrospective study, factors such as academic term, tooth type, and the presence of crowns were identified as influential prognostic factors for endodontic

treatment outcomes. It has been observed that 4th year students tend to exhibit higher success rates as compared to their 5th year counterparts. Upon closer inspection, it can be inferred that this is likely due to the fact that the dental cases treated in 4th year are typically less complex in nature, often involving anterior and premolar teeth. This ultimately results in a higher likelihood of successful treatment outcomes for these students. In addition, more favorable treatment results were obtained in patients older than 42 years and in maxillary premolars. Emphasizing the enhancement of endodontic education during undergraduate dental training is essential to achieve better treatment results. It is anticipated that future studies focusing on this topic and encompassing student clinics from different universities will be beneficial for evaluating the success of endodontic treatments conducted by dental students.

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Case Report

Four Year Follow-up of a Mandibular Second Premolar Tooth with Three Canals and Large Periapical Lesion After Retreatment: A Case Report

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CLINICAL SIGNIFICANCE

It is crucial to ensure that the root canal system is thoroughly cleaned. In cases where the tooth has already undergone root canal treatment and has a large periapical lesion, non-surgical endodontic treatment should be the first course of action.

ABSTRACT

90% of mandibular second premolars typically have a single root canal from the orifice to the apical foramen. However, there may be rare cases where different canal numbers are present. In this instance, a four-year follow-up of a three-canal mandibular second premolar tooth with a rare anatomical variation and a large periapical lesion that had previously undergone root canal treatment was presented. The retreatment was performed using ProTaper Universal D1, D2, and D3 retreatment files and irrigated using 2.5% sodium hypochlorite, 17% ethylenediaminetetraacetic acid, and saline. During the patient's 7th-month follow-up, significant bone formation was observed in the periapical region, and at the 48th-month follow-up, the lesion size had substantially reduced. Radiographic examination revealed changes in densities within the lesion, reconstruction of the trabecular structure, formation of lamina dura in the apical region, asymptomatic formation of the teeth during clinical examination, and healthy soft tissues, all indicating a successful treatment. It is essential to note the significance of the Cone Beam Tomography imaging system in identifying canal variations, which should be used appropriately to increase treatment success. As demonstrated in this case, the first approach for a root canal-treated tooth with a large periapical lesion should be non-surgical endodontic treatment.

1. Introduction

To ensure a successful endodontic treatment, it is important to have a clear understanding of the anatomy of the root canal system. Clinicians may encounter various root canals with different sizes, shapes, and numbers. Failure to identify anatomical variations can result in inadequate instrumentation and obturation, leading to treatment failure.[1] Lesion size has been associated with a richer intra-radicular microbiota in terms of bacterial counts and species.[2] Arguably, this could pose a bigger challenge to adequate disinfection. Less than adequate root canal disinfection would negatively impact healing of apical periodontitis. Form a clinical standpoint, decreased success rates of non-surgical root canal treatment when lesion exceeds 5 mm in size [3] and negative correlation between apical lesion size and treatment success [1,4] are evidence for the lower treatment outcome expectations when large lesions are to be treated non-surgically. Despite the fact that a recent meta-analysis investigating the size of the periapical lesion on the success rate of different endodontic treatment modalities has reported significantly lower success rates of non-surgical root canal treatment in large lesions, it concludes that no endodontic treatment modality is superior than the others when treating large lesions.[5] Also, there is ample clinical evidence of complete radiographic healing of large-sized apical lesions.[6-8] Thus, from a clinical decision-making point of view, non-surgical root canal treatment is considered justifiable as the first treatment choice for large-sized apical lesions.

The root and canal morphology of some mandibular second premolars (Mn2P) can be extremely complex and requires careful consideration. The canal type seen in 90% of Mn2P is a single root canal from the orifice to the apical foramen.[9] The prevalence of Mn2P with two canals was reported as 1.2% [10] for the Mongoloid population and 22.8% [11] for the Jordanian population. The prevalence of Mn2P with three canals was reported only as 0.4%.[12] Genetic and racial variations are factors that can affect root canal morphology.[13] Besides, the design of the study, the method used for root canal system identification, and the sample size are some of the other factors that contribute to the results of prevalence studies.

Many different methods such as plastic resin injection [14], conventional radiographs [10], sectioning [15], scanning electron microscope [16], irrigation and colouring of tooth roots [17] and cone beam computed tomography (CBCT) [18] have been used to study root canal morphology. Since conventional radiographs can only obtain images in the buccolingual direction, they may not always be sufficient for an accurate morphological assessment. In some clinical cases, CBCT is used to provide further information on root canal morphology. In cases where there are large periapical lesions, it is strongly advised to perform a cone beam computed tomography (CBCT) examination.[19]

The primary objective of this research endeavor is to present the four-year follow-up findings of a retreatment procedure performed on an Mn2P with three canals that featured a large periapical lesion and indicated symptoms such as sensitivity to both palpation and percussion after a root canal treatment.

2. Case Presentation

A 21-year-old Turkish man visited the Department of Endodontics at Recep Tayyip Erdogan University's Faculty of Dentistry with a complaint about his right Mn2P tooth. The patient had been experiencing recurring but not severe pain. During a clinical examination, it was discovered that the tooth was sensitive to both palpation and percussion. The radiological examination revealed that the tooth had previously received poor treatment, resulting in a large periapical lesion (Fig. 1A).

During the dental procedure, a rubber dam was placed to isolate the affected tooth and the coronal restoration material was removed. The dentist then employed the ProTaper Universal D1, D2, and D3 retreatment files with a speed and torque controlled motor (VDW Silver; VDW, Munich, Germany) to remove the canal filling. Then, a periapical radiograph was taken with manuel K-type files (Fig. 1B). To accurately determine the size of the lesion and estimate the canal variation, a CBCT scan was taken. CBCT images were attained by the Planmeca Promax 3D Classic (Planmeca, Helsinki, Finland) device and 90 kVp, 4-10 mA, and 200 µm high-sized parameters. CBCT images were formed on Planmeca Romexis software (Planmeca Romexis 4.6.2.R, Planmeca, Helsinki, Finland). To accurately assess the configuration of the root and root canal system, axial slices (coronal, mid-, and apical third) were evaluated in every third slice, along with sagittal and coronal slices. From the CBCT slices, it was found that the mandibular second premolar had three roots and a root canal in each root (Fig. 2).

To determine the working length in the mesiobuccal, distobuccal, and lingual canals, an apex locator (Root ZX Mini Apex Locator, J. Morita, USA) was used and later verified with a radiograph. The root canals were prepared with the ProTaper Universal system (Dentsply-Maillefer, Ballaigues, Switzerland) to instrument all canals up to F1. A solution of 2.5% sodium hypochlorite (NaOCl) that was constantly refreshed to ensure efficiency (Total 10 ml) was used.[20] To completely eliminate the smear layer, a thorough 17% ethylenediaminetetraacetic acid (EDTA) wash (2 ml for each canal), which was followed by another wash with NaOCl (2 ml) was employed. In between the NaOCl-EDTA washes, distilled water was used to ensure proper cleansing. The activation of the solution was accomplished manually with the aid of gutta-percha points, which ensured precision and accuracy in the process. A 27 gauge irrigator needle (Ultradent Endo Eze, Ultradent, Turkey) was used for irrigation. Once the preparation phase was complete, the canals were dried with paper points and filled with calcium hydroxide (Kalsin; Spot Dis Deposu AS, Izmir, Turkey). A temporary coronal restoration was placed with Cavit (ESPE, Seefeld, Germany), and the patient was scheduled for a follow-up appointment a week later.

After one week, the patient showed no symptoms and the calcium hydroxide medicament was removed by using master apical file instrument in combination with 17% EDTA solution.[21] ProTaper F2 (Dentsply-Maillefer, Ballaigues, Switzerland) was used for the final preparations of the canals with the irrigation protocols mentioned above. The procedure was terminated once the criteria of no outflow of canal filling debris during irrigation, absence of filling material on files or paper cones, and visible clean canal walls were met. Then, a radiograph was taken with master apical cones (Fig. 1C). After verifying the working length with cones, the canals were dried with paper points and root canal obturation was completed with a resin-containing root canal sealant (AH Plus,

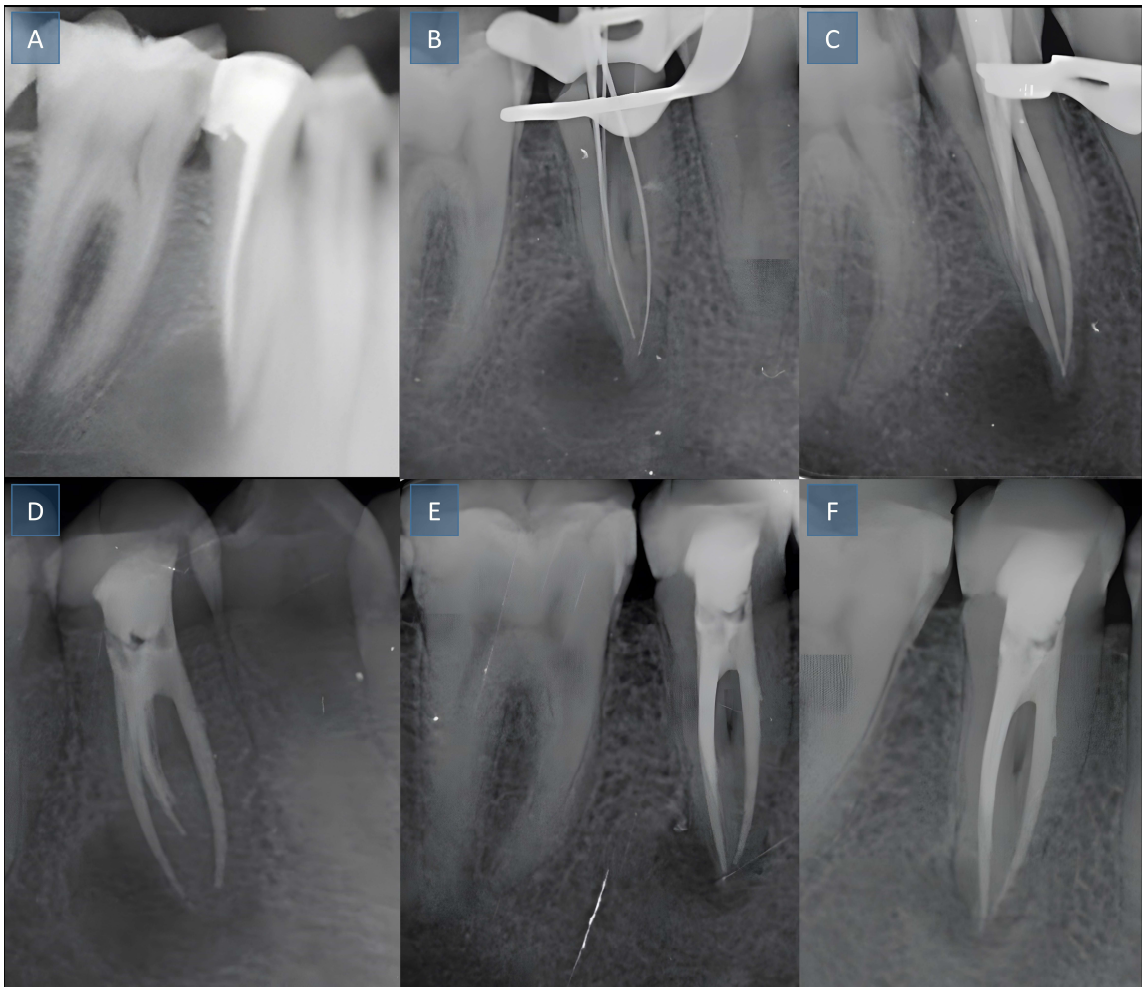

Fig. 1. Periapical radiograph of the right mandibular second premolar (A) before the retreatment, (B) with manuel K-type files, (C) with cones, (D) after completion of retreatment, (E) after 7th month, (F) after 48th month

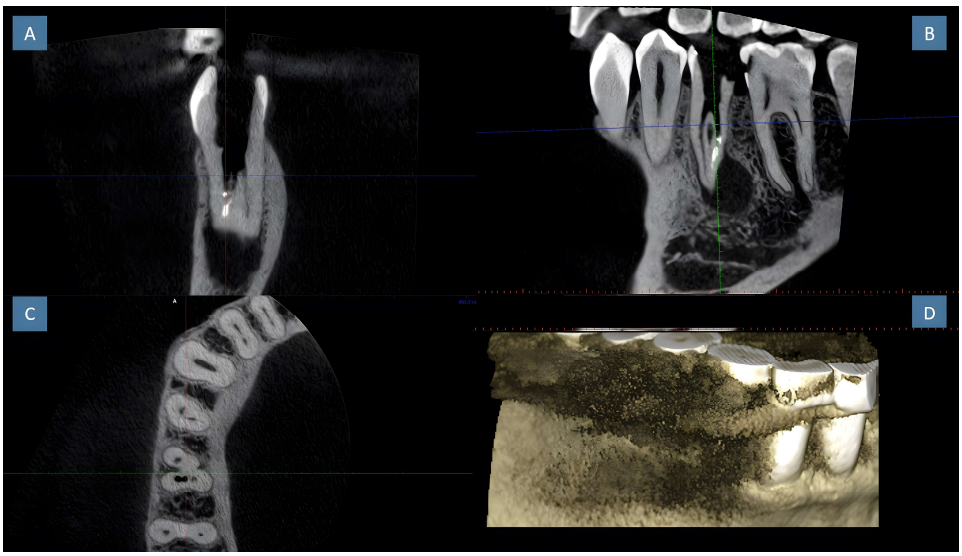

Fig. 2. The CBCT sections that are displayed in four different views: (A) Coronal, (B) Sagittal, (C) Axial, and (D) a three-dimensional image.

Dentsply DeTrey GmbH, Konstanz, Germany) and compatible gutta-percha (Diadent, Seoul, South Korea). The permanent coronal restoration was done with composite resin (Filltek P60, 3M Dental Products, St. Paul, MN, USA) and a final periapical radiograph was taken to confirm the completion of the treatment (Fig. 1D). The patient was informed about the tooth's morphology and the size of the periapical lesion, and that follow-up appointments should be scheduled at certain intervals. The patient returned to the clinic 7 months later and a periapical radiograph showed significant healing of the lesion (Fig. 1E) with no clinical problems. A follow-up 4 years later showed smaller periapical lesion dimensions in the radiograph (Fig. 1F), and the patient was instructed to return for further control.

3. Discussion

It is important for proper treatment and a positive outcome to have a thorough understanding of the intricate anatomy of mandibular premolars.[10] Incomplete cleaning and filling of root canals, leading to unsuccessful endodontic treatment [22], can occur if there is insufficient knowledge of the anatomy. Clinicians must be mindful of any variations that may exist and be familiar with the normal root canal system's anatomical morphology.

During endodontic treatments, periapical radiographs are commonly used for anatomical evaluations of teeth. However, in cases where the canals have different root canal configurations, like in this situation, periapical radiographs may not provide sufficient information. To better visualize the canals, radiographs taken at different horizontal angles can be used. CBCT is considered a suitable technique for precise investigation of root canal systems and detailed determination of anatomy as the anatomy of a tooth can be observed three-dimensionally from different angles, allowing for both qualitative and quantitative evaluations of its characteristics.[18] CBCT has been used for identifying the root and root canal system configurations in cohorts with similar characteristics both at the demographic and tooth-level as the patient and tooth described in this case report, corroborating the rare anatomical variation treated.[23,24]

The treatment of mandibular premolars can be challenging due to their complex canal systems, making them one of the most difficult teeth to address in endodontics.[25] Nevertheless, advancements in imaging systems, loop and operating microscope magnification tools, and updated knowledge on the anatomy of these teeth have led to improved success rates in even the most demanding cases. There have been numerous studies in the literature regarding the anatomical variations of mandibular premolar teeth, specifically the second premolars.[9,25,26] Briseño-Marroquín, et al. [27] identified the root canal system configuration of these teeth as typically having a single root and canal. However, other studies have reported variations in the root canal morphology. In fact, the occurrence of a second canal in mandibular second premolars has been found to be relatively rare, with a prevalence of only 2% in Iran [28] and between 5.8–17.5% in Mexico [10]. It is important to consider genetic and racial differences when examining root canal anatomy and morphology.[25] In a study conducted in Turkey, Sert, et al. [29] found that 7% of Mn2P had two root canals. Another study conducted in Turkey by Çalişkan, et al. [26] reported that the occurrence of three canals in Mn2P was 0%.

Insufficient cleaning and filling of a root canal can lead to microbial infection, resulting in endodontic treatment failure.[30] If initial root canal treatment fails, retreatment should be considered as the first option. Adequate biomechanical cleaning of the root canal system is the most critical factor for healing in teeth with periapical lesions. Calcium hydroxide is commonly used as an intracanal endodontic material, as it has a high alkalinity tissue dissolving effect, induces hard tissue formation, and has a bactericidal effect.[21] In this case study, the patient was given calcium hydroxide, and significant bone formation was observed in the periapical region in the seventh month follow-up visit. After each root canal treatment, it is necessary to evaluate the periapical lesion to ensure proper healing. In this study, the size of the lesion was greatly reduced after 48 months of observation, indicating successful treatment.

4. Conclusion

It's important for all clinicians to understand that root canals can have a variety of canal morphologies and anatomy. If the canal system isn't completely cleaned before treatment, it's likely that the treatment will fail. That's why it's crucial to examine the tooth's anatomy before beginning endodontic treatment. Using a CBCT imaging system can help identify variations in the canal and improve the chances of success. In cases where there is a large periapical lesion, non-surgical endodontic treatment should be the first approach for a tooth that has already undergone root canal treatment.

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