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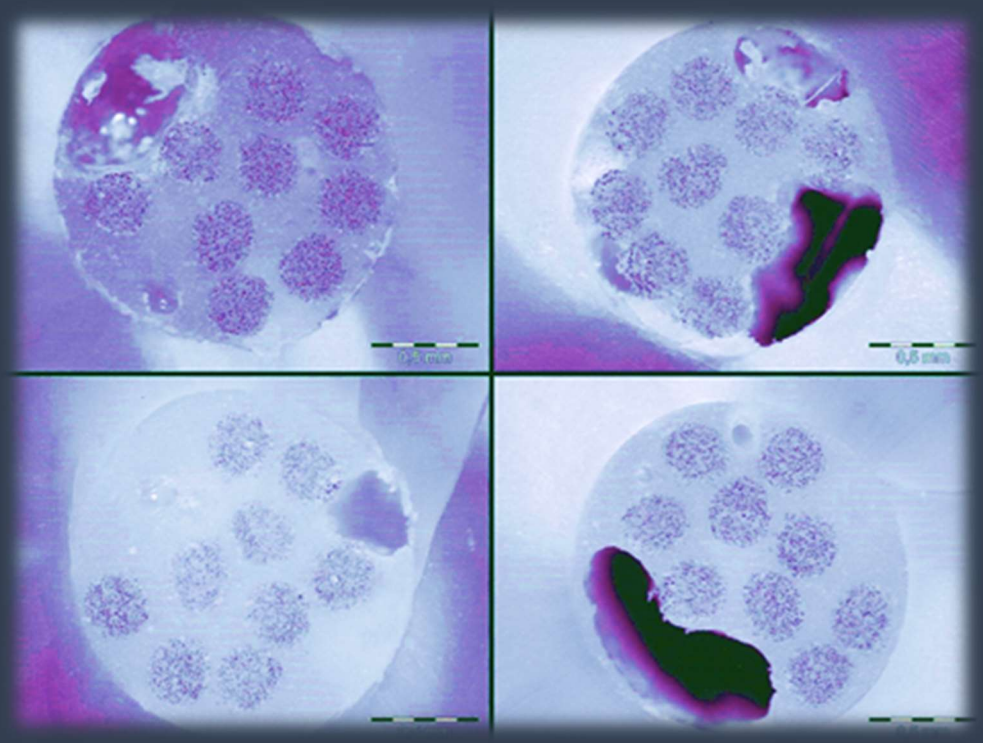

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Aims & Scope

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

Original Article

Comparative Analysis of Push-Out Bond Strength Between Prefabricated Solid Glass Fiber Post and Bundled Glass Fiber-Reinforced Resin Post

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CLINICAL SIGNIFICANCE

The Rebilda post GT system, requiring less dentin removal and simpler preparation, provides a comparable bond strength to the Reforpost, making it a preferable choice for minimizing tissue loss and simplifying the procedure.

ABSTRACT

Objectives: The objective of this study was to conduct a comparative analysis of the push-out bond strength between a prefabricated solid glass fiber post and a bundled glass fiber-reinforced resin post at the coronal, middle, and apical thirds.

Materials and Methods: The crowns of twenty extracted human mandibular premolars were removed to obtain the root length of 17 mm. After canal extension and fillings were completed, two groups were prepared from roots randomly: bundled fiber (Rebilda Post GT-RB) and solid fiber (Reforpost-RF). The canal preparation was made for the Reforpost with its own drill. Posts were cemented into root canals with dual-cure resin cement. The roots were embedded in cylindrical acrylic blocks. Six sections were obtained from a root. A push-out test was applied to the post surface by a universal test machine. The debonding value between the post and dentin surface was recorded in Newton and converted to MPa using the formula.

Results: The push-out bond strength values displayed no significant variance among the post systems across all root thirds ($p>0.05$). Nonetheless, a notable distinction was noted between the root regions of RF ($p=0.032$), with the middle third demonstrating higher bond strength values compared to the coronal third. Conversely, for RP, no significant variance was observed between root regions ($p>0.05$).

Conclusion: Rebilda Post GT showed similar results to those of Reforpost in terms of push-out bond strength between post and root canal dentin. It has not been found to have an advantage over solid fiber posts.

1. Introduction

Dental caries, substantial material loss, or the creation of an access cavity for endodontic therapy can lead to substantial loss of tooth structure. Intraradicular posts are utilized to provide support for crown restorations[1] in order to reconstruct endodontically treated teeth with significant coronal destruction and to minimize stress transferred to the tooth.[2] The fragility of pulpless teeth is primarily attributed to the loss of supporting tissues due to various factors. As a result, the risk of fracture significantly increases following endodontic treatment.[3]

Coronal preservation of tooth tissue, selection of posts with elastic properties similar to dentin, and effective post adhesion are critical determinants for the successful clinical outcome of restored endodontically treated teeth.[1] In the restoration of pulpless teeth, custom or prefabricated posts may be employed. Fiber posts, due to their mechanical properties resembling those of natural tooth structure, offer a more uniform distribution of stress within the root, thereby reducing the likelihood of failure. Consequently, they represent a viable alternative[1,2], characterized by favorable aesthetics, cost-effectiveness, and similarity in properties to dentin, particularly in terms of flexural strength and elasticity modulus.[4]

Teeth restored with glass fiber posts demonstrate a lower susceptibility to fracture in comparison to those restored with metal or zirconia posts. This is attributed to the incomplete transfer of forces to the root, and the capacity of polymerized resin cement to reinforce the root.[1,5] However, prefabricated posts may not perfectly conform to root canal preparation, leading to variations in cement thickness.[6,7] The primary reported failure associated with such restorations is loss of retention. The survival rate of posts is significantly influenced by their adaptation to the root canal's anatomy.[8] Challenges arise from the relatively low bond strength achieved during cementation procedures.[9] An inherent limitation of glass fiber posts is their standardization of post diameters, which may result in poor adaptation to the root canal and necessitate additional canal preparation or the use of smaller diameter posts.[10,11]

Reforpost (RF) is a prefabricated post designed as a single-piece, parallel, serrated, and conically shaped glass fiber system with three different thicknesses. It exhibits a modulus of elasticity similar to dentine and presents good retention, facilitating adaptation to the root canal. It is asserted that its reduced removal of tooth tissue in the apical third provides protection to the dentin in this area and diminishes the risk of root fracture. The post's parallel structure facilitates mechanical interlocking with the root canal walls.[12]

The Rebilda Post GT (RB) constitutes a glass fiber reinforced composite post system, encompassing four distinct post sizes distinguished by color codes, each comprising a specific number of posts. The blue-coded posts consist of four 0.8 mm diameter posts, the red-coded posts comprise six posts with a 1 mm diameter, the green-coded posts entail nine 1.2 mm diameter posts, and the black-coded posts encompass twelve 1.4 mm diameter posts. This assembly of slender posts facilitates effortless insertion into various root canal morphologies. The system is designed to reduce the requirement for mechanical preparation of root canals, thus preserving the integrity of the tooth structure and enhancing retention values through increased surface area in restorations.[13]

While several existing studies[14,15] have examined the impact of solid and bundled posts on bond strength, it is crucial to validate these findings through further research. This research project aimed to conduct a comprehensive comparison of the push-out bond strength between a standardized prefabricated glass fiber

post and a bundled glass fiber-reinforced resin post. The objective is to assess the bond strength across all root thirds. The null hypotheses (H0) of the study are as follows: 1) Post systems have similar bond strength values, 2) Different root regions have similar bond strength values.

2. Materials and Methods

2.1. Study design

The study was conducted in accordance with the approved protocol by the Yıldırım Beyazıd University Ethics Committee with decision number 2019-235. A total of 20 human mandibular premolar teeth were utilized for the study. The teeth were divided into two groups: one treated with RF and the other with RB (n=10 for each group). The crowns were removed under water cooling, ensuring a root length of 17 mm, and the working length was determined as 16 mm.

Initial access to the canal was established using a #15 K-file and an Endo-Mate TC2 (NSK, Frankfurt, Germany) endodontic motor. The root canals were shaped with a OneShape (MicroMega, Besançon, France) ISO 25 tip and a 6% taper file as per the manufacturer's recommendations. Throughout the shaping process, the canals were irrigated with 1 ml of 2.5% NaOCl using 2 ml injectors with 27-gauge needles. Final irrigation of the root canals was performed using 2 ml of 17% EDTA (pH 7.6, 3 minutes), followed by 2 ml of 2.5% NaOCl (1 minute), and 5 ml of distilled water. The canals were subsequently dried with paper points.

For filling, a 25 tip and 6% taper master gutta-percha cone, along with #20-#25 cones and sealer (AH 26, Dentsply, Sirona, USA) were used. Access cavities were temporarily restored using CavitG (3M ESPE, Seefeld, Germany). The treated teeth were stored at 37°C and 100% humidity for 7 days. Post space was prepared for Reforpost (Angelus, Brazil) using #2 Largo drills, while no mechanical preparation was made for RB (VOCO, Cuxhaven, Germany).

Following post space preparation, the canals were irrigated with 2 ml of 17% EDTA (pH 7.6, 3 minutes), 2 ml of 2.5% NaOCl (1 minute), and 5 ml of distilled water. Paper points were utilized for drying the canals.

The posts were affixed to the root canals using dual cure resin cement (Panavia SA Cement Plus, Kuraray Inc., New York, USA). The resin cement was dispensed from a syringe onto the tube end and then distributed over the canal surfaces using a #40 lentulo. Once the post was inserted into the canal with finger pressure, the cement was cured using a light-curing device (Elipar, 3M ESPE, Seefeld, Germany) for 40 seconds.

The tooth roots were encased in acrylic within round acrylic blocks measuring 20 mm in diameter. Six 1 mm-thick sections, two from each of the coronal, middle, and apical thirds of the root, were obtained using a precision cutting device (Metkon Micracut Precision Cutter, Metkon, Bursa, Turkey) with water cooling.

A universal test device (Lloyd LR10K Plus, Ametek Inc., United Kingdom) was employed to conduct push-out tests at a crosshead speed of 0.5 mm/min. The 1 mm diameter pin was positioned at the center of the force application surface, and the measured bond strength values were recorded in Newton (N) and subsequently converted to megapascal (MPa) units using the formula MPa = N/A, where A= 2πrh, with π being 3.14, r representing the radius of the intraradicular space, and h denoting the disc height.

Table 1. Mean push out bond strengths (MPa) with standard deviations.

Material/Root level	Coronal third	Middle third	Apical third	p-value
RB	4.398±2.120[a]	5.211±3.049[a]	5.273±3.382[a]	0.085[2]
RF	3.802±1.706[a]	6.157±3.395[b]	5.331± 3.701[ab]	**0.032**[2]
p-value	0.479[1]	0.363[1]	0.445[1]	

[1] independent student's t-test, [2] One-way ANOVA Tukey-post hoc test

2.2. Scanning electron microscopy analysis

The failure type of each specimen was determined using a stereomicroscope (Leica S8 APO, Leica Microsystems, Wetzlar, Germany). Adhesive failure was characterized into three categories: cement-dentin adhesion failure, post-cement failure, and mixed-type failure. Cement-dentin adhesion failure refers to the separation of cement from dentin, while post-cement failure involves the separation of cement from the post. Mixed-type failure was defined as the concurrent occurrence of these bond failures. Subsequently, one sample from the coronal in each group underwent scanning electron microscopy (SEM) analysis (FEI Quanta 450 FEG, FEI, Oregon, USA) both before and after the push-out test.

2.3. Statistical analysis

The statistical analysis was conducted using the SPSS 21.00 software (SPSS Inc, Chicago, USA). To validate normality and homogeneity across groups, the Shapiro-Wilk test and Levene's test were performed. Normal distribution and homogeneity were confirmed. When comparing the push-out bond strength values between the coronal, middle, and apical thirds, a one-way ANOVA and Tukey post-hoc test were utilized. For the comparison of push-out bond strength values between different post systems, an independent student's t-test was employed. The significance level was set at $p<0.05$.

3. Results

The push-out bond strength values showed no significant difference between the post systems in all root thirds ($p>0.05$). However, a significant difference was observed between the root regions of RF ($p=0.032$), with the middle third exhibiting higher bond strength values than the coronal third. For RP, no significant difference was found between root regions ($p>0.05$) (Table 1).

Following the bond strength test, the SEM examination revealed inhomogeneous areas in the resin cement (Fig. 1). In the RF group, mixed failure and cement-dentin failures were equally prominent. In contrast, the RB group exhibited mix-type failure as the most common and cement-post interface failures as the least common (Fig. 2).

Samples of one coronal section from both post materials were examined by SEM before and after the push-out test. Unlike the distribution of fine fibers of the RB in the resin cement, the resin cement surrounding the surface of the RF did not exhibit splitting, although surface separations were observed after the push-out bond strength test (Fig. 3).

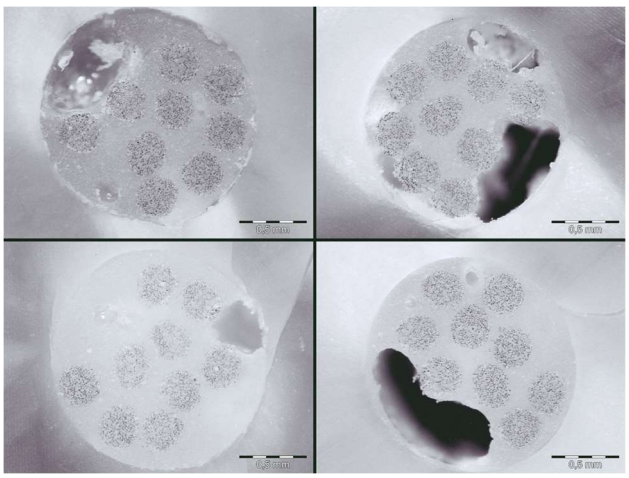

Fig. 1. Inhomogenities in the resin cement.

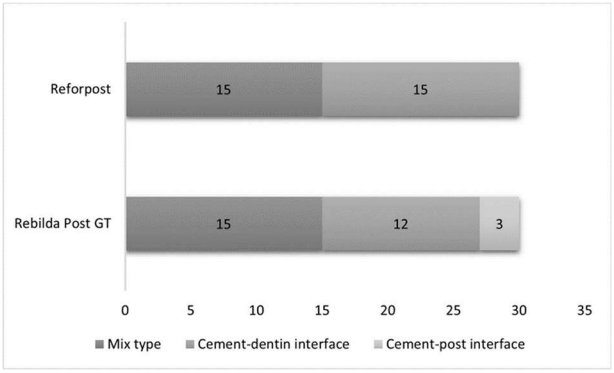

Fig. 2. Failure types of the post specimens. (Failure of dentin adhesion, separation of cement from dentin; failure of post adhesion, separation of cement from post; mixed type failure was evaluated as the coexistence of the mentioned bonds.)

4. Discussion

Solid and bundled post systems are crucial in the restoration of endodontically treated teeth, providing necessary support and stability for subsequent restorative procedures. Solid post systems, often made of metals or carbon fibers, offer high strength and durability but may require more extensive tooth preparation and can sometimes compromise the remaining tooth structure. Bundled post systems, typically composed of fiber-reinforced composites, offer advantages such as better adaptation to the canal morphology, preservation of more tooth structure, and improved aesthetics. They distribute stress more evenly and have a modulus of elasticity similar to dentin, which reduces the risk of root fractures. However, the choice of post system depends on various factors including the extent of tooth damage, aesthetic requirements, and the specific clinical situation.[16-18]

In this study, solid (RF) and bundled (RB) post systems were compared for their bonding ability to the root canal systems. The results indicated that both bundled glass fiber-reinforced resin post (RB) and glass fiber post (RF) demonstrated similar bond strength values, leading to the acceptance of the first null hypothesis. This finding aligns with previous research by Alves et al.[15], which evaluated the bond strength of single prefabricated glass fiber posts and bundled glass fiber-reinforced resin posts in weakened roots. Their results showed that while the individual prefabricated and bundled systems had distinct characteristics, their bond strength values were comparable, supporting the notion that both systems can be effective in clinical applications.

Additionally, a study by Abreu et al.[14] focused on the bond strength of cemented fiber posts in teeth with simulated internal root resorption, further supporting the conclusion that the bonding performance of different fiber post systems can be quite similar under various conditions. They found that both single prefabricated and bundled posts showed adequate bonding strength, suggesting that either system can be chosen based on clinical preference and specific case requirements.

The design of a post can significantly impact its bond strength and retention in the root canal. Research indicates that parallel posts are more conservative in nature compared to tapered and double-tapered posts. In the current study, we utilized a parallel structure serrated post (RF). Surface modifications applied to the post can enhance post retention.[19] Literature suggests that the serrated form of RF enhances the bonding between the resin cement and the post, thereby increasing retention.[20]

The production of prefabricated glass fiber posts adheres to

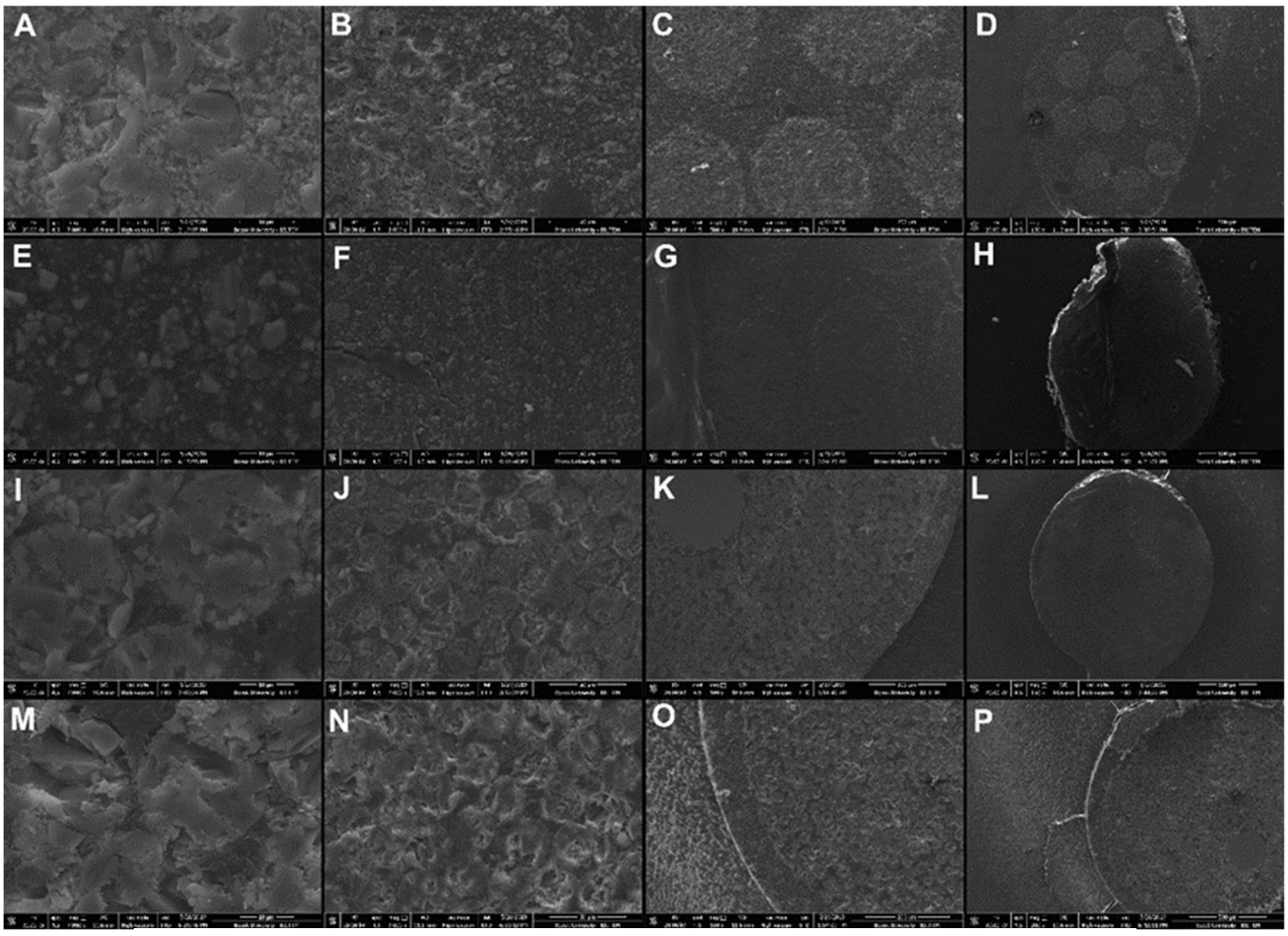

Fig. 3. SEM images of RB (A-H) and RF (I-P) coronal slices before (A-D; I-L) and after (E-H; M-P) push out strength tests.

The production of prefabricated glass fiber posts adheres to specific standards, necessitating adaptation to the root canal through mechanical preparation or selection of the closest post diameter.[10] Cast metal posts are manufactured to conform to the root canal shape using direct or indirect techniques.[21] CAD/CAM milled glass fiber posts demonstrate superior adaptability to root canals compared to prefabricated fiber posts, reducing cement thickness.[22] Glass fiber and cast metal posts produced with CAD/CAM exhibit better bond strength than prefabricated glass fiber posts due to their compatibility with the root canal. The bundled glass fiber-reinforced resin post utilized in our study can be conveniently inserted into the root canal without requiring special post preparation. Post adaptation to the root canal is believed to positively impact bond strength, making the RB bundled fiber post advantageous in root canal compatibility. We compared the push-out bond strengths of RB bundled fiber post and RF solid prefabricated glass fiber post, yielding similar values. Notably, a separate study comparing solid glass fiber posts and bundled glass fiber-reinforced resin posts also produced similar results.[23] However, variations in luting agents, adhesives, and test conditions may influence the attainment of lower bond strength values. Inhomogeneous distribution of the resin cement, as observed in this study, and varying fiber numbers and insertion processes into the root canal could lead to void formation and differing bond strength results. Kharouf et al.[24] reported similar risks of void formation for solid fiber and bundled fiber, contrasting Bitter et al.[23], who indicated that bundled fiber contains more voids than the solid post. Additionally, the presence of six or twelve fiber bundles in the RB post did not significantly affect bond strength, producing comparable values to the solid post.

In the context of post placement, dual cure resin cements are considered a highly reliable option for ensuring thorough polymerization across the entire post area. Although they are capable of polymerizing in the absence of light, their mechanical properties are significantly enhanced when light curing is incorporated. Hence, the usage of light curing in conjunction with dual cure cements is commonly recommended.[1] Studies have indicated that dual cure resin cement can effectively enhance the degree of polymerization, particularly in areas like the apical third where polymerization is challenging due to moisture and contamination. This is attributed to the elimination of the detrimental effects caused by these factors in the apical region.[25] In current research, dual cure resin cement was employed for both posts. Discrepancies may exist in the occupied area between the RB and RF post in the root compared to the canal volume, as well as in the amount of remaining cement between these posts and the dentin surface. Nevertheless, it has been reported that the enlargement of post space and the subsequent increase in cement thickness do not compromise the push-out bond strength of fiber-reinforced composite resin posts to root dentin.[25]

In the present investigation, it was observed that the coronal third of the RF demonstrated significantly lower bond strength compared to the middle third. Conversely, Bitter et al.[23] noted a significantly lower bond strength in the apical third of the RB post. Another study[27] utilizing translucent fiber posts found no statistically significant variations in push-out bond strength values across different thirds. Duarte Santos et al.[27] conducted a study employing two different resin cements and determined that resin cement and root thirds did not significantly impact push-out bond strengths and failure modes. The current research yielded similar bond strength results across various root thirds solely for RB. It is important to note that the moisture present in the apical region under in vivo conditions was not simulated in the present study. The primary limitation lies in the inability of in vitro test conditions to effectively replicate natural conditions.

Research suggests that the quantity of fibers in the composite fiber bundle utilized in this investigation may influence the thickness of the resin cement. Unlike solid posts, where the post is entirely surrounded by a layer of cement, the cement application around bundled fibers is disrupted due to the presence of fibers in the resin cement. Studies have demonstrated that variations in cement thickness can significantly affect bond strength. For instance, a study by Marcos et al.[28] showed that customized posts with a thicker cement layer had higher bond strength compared to posts with thin or very thick cement layers. Similarly, D'Arcangelo et al.[29] found that the highest bond strength was achieved with an intermediate cement thickness, indicating that overly thick or thin cement layers can reduce bond strength.

Moreover, the operator is believed to be a significant factor in the proper placement of the RB post in the root canal. The potential impact of air bubbles, which may form during the insertion of the bundled fiber post, on the fracture strength of the restoration and root, as well as on the stress exerted on the root surface, should be carefully considered. Air bubbles and voids can compromise the mechanical integrity and bond strength, as highlighted by Grandini et al.[30], who observed gaps and bubbles within the cement layer when fiber posts were not properly adapted.

It is suggested that further research would be beneficial in evaluating resin cement thickness, the quantity of fibers within the fiber bundle, stresses on the root surface, and fracture strength. Additionally, comparing the influence of adapting the RB post to the canal on bond strength with CAD-CAM milled fiber posts and cast posts is crucial to determine the efficacy of chairside application. Studies by Farid et al.[31] have shown that increasing cement thickness can reduce bond strength with self-adhesive cements, while self-etch adhesives are less affected.

5. Conclusion

The bundled fiber post demonstrated comparable push-out bond strength to the solid fiber post across all thirds of the root. It was observed that the bundled fiber post did not present an advantage over the solid fiber post in this regard. However, the parallel form of the RF post necessitates more extensive root canal preparation to achieve a parallel form within the root canal space. Conversely, RB post only requires the removal of the root canal filling material for intracanal placement. Furthermore, the insertion of an RF post into the root canal results in greater tissue loss compared to the placement of an RB post. Both systems exhibited similar push-out bond strength to the root canal walls. Consequently, the RB post offers an advantage over the RF post as it requires no dentin removal from the root canal walls.

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M. U. : Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing, E. S. : Methodology, Formal analysis, Writing - Review & Editing

Conflict of Interest

The authors declare that no conflict of interest is available

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Original Article

Evaluation of the Color Stability of Newly Introduced Turkish Dental Composite Resin Products: An In Vitro Study

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Color Stability
In-vitro study

CORRESPONDENCE

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CLINICAL SIGNIFICANCE

The study's results highlight that newly introduced Turkish composites offer similar color stability to established composites, suggesting their effectiveness for long-term dental restorations and providing reliable options for dental practitioners.

ABSTRACT

Objectives: This study aimed to evaluate the color stability of dental composites originating from Turkey by comparing Filtek Z550.

Materials and Methods: Four different solutions (Distilled water, tea, coffee, and cola) and four nanohybrid composites (Nova Compo C, RubyComp P, Astor Plus, and Filtek Z550 were used in the study. Composite specimens with a diameter of 8 mm and a thickness of 2 mm were produced using a cylindrical silicone mold. Both the top and bottom of the composites were cured with the B-Cure Plus curing light for 20 seconds. A total of 160 samples were obtained, 40 from each composite (n=10). The first shade measurement of the samples was carried out with a spectrophotometer device according to the CIE L* a* b* shade system. Color measurements were carried out on the 1st, 3rd, and 7th days.

Results: Nova Compo C, RubyComp P, and Filtek Z550 exhibited significantly higher color stability than Astor Plus ($p<0.001$). However, no significant difference was found between other dental composites ($p>0.05$). Distilled water and Cola caused significantly lower discoloration than tea and coffee; however, no significant difference was found between distilled water and cola ($p>0.05$). Discoloration increased significantly from day 1 to day 3 and from day 3 to day 7 ($p<0.001$).

Conclusion: Dental composite products newly introduced dental composite products in Turkey exhibited similar color stability when compared to Filtek Z550. Only Astor Plus exhibited lower color stability than others. The novel dental composite products originating from Turkey are promising regarding color stability.

1. Introduction

With the development of aesthetic perception and the increasing demand for esthetically pleasing dental restorations, the desire for a more beautiful smile has become a significant focus in dental clinics. Modern dentistry aims to restore lost dental tissues as naturally and effectively as possible, thereby enhancing both function and appearance.[1] In this context, resin-based dental composites (RBCs) have become widely used due to their excellent aesthetic properties, versatility, and ability to mimic the natural appearance of teeth. RBCs are composed of a resin matrix and filler particles, which together provide the necessary mechanical strength and aesthetic qualities required for dental restorations.[2] Their popularity is largely due to their ability to be color-matched to the patient's natural teeth, providing a seamless and visually appealing restoration.

However, despite their many advantages, RBCs are not without their limitations. Intrinsic factors such as changes in the filler, organic matrix, and silane in the composite resin content, as well as external factors like fluid absorption from the outside, can cause discoloration. The intrinsic factors primarily involve the chemical composition and structure of the resin matrix, including the type and amount of filler particles and the efficiency of the polymerization process.[3] For instance, a higher degree of conversion and a more stable resin matrix can enhance color stability. On the other hand, extrinsic factors, including dietary habits and the presence of staining agents like coffee, tea, and cola, contribute significantly to the discoloration of RBCs.[4] These beverages contain pigments and acids that can penetrate the resin matrix, leading to changes in color over time.[5]

Many methods such as visual assessment, colorimeters, spectrophotometers, digital cameras, and spectroradiometers can be used to measure color in dentistry. Each method offers unique advantages and limitations. Visual assessment, though widely used, is subjective and can be influenced by the observer's perception and lighting conditions. Colorimeters provide more objective measurements by quantifying color based on specific parameters, but they may lack the sensitivity required for detecting subtle differences in color shades. The spectrophotometer is the most preferred among these methods because of its advantageous properties such as higher sensitivity, repeatability, and ability to discriminate metamerism. It provides detailed spectral data across a wide range of wavelengths, allowing for precise and consistent color measurements.[6]

Color stability of dental composites originating from Turkey has not been evaluated yet. Filtek Z550 is a widely used dental nanocomposite that has proven its color stability in the previous studies.[7-9] Thus, while comparing the RBCs, Filtek Z550 was allotted as a control group. This study aimed to evaluate the color stability of RBCs originating from Turkey by comparing Filtek Z550. The aims of the present study were to test the following null-hypotheses:

1. There is no significant difference between dental composites regarding color stability.
2. There is no significant difference between solutions in terms of discoloration..
3. There is no significant difference between time periods regarding color stability.

2. Materials and Methods

2.1. Study design

Four different solutions and four nanohybrid composites were used in the study. The solutions included distilled water, tea

Table 1. The properties of the composite resins used in the study.

Composite resins	Composition	Manufacturer
Nova Compo C	The monomer matrix is composed of different dimethacrylates (18–22% weight) and ULS® (Ultra Low Syhrinkage)Monomer. The fillers contain barium glasses, ytterbium and prepolymer (83–78 % weight), additives, catalysts, stabilizers and pigments.	Imıcyrl, Turkey
RubyComp P	Methacrylate polymer (20%), inorganic fillers (80%), barium glass, mixed oxides, copolymers, photoinitiator, and stabilizer	Rubydent, Incidental, Turkey
Astor Plus	Bis-GMA, UDMA, TEGDMA based composite resins, inorganic fillers (77-78%), fillers silica, quartz, pigments, initiators	Dentac, Öncü Dental, Turkey
Filtek Z550	Silane treated ceramıc Bisphenol a polyethylene glycol dietherdimethacrylate Bisphenol a diglycidyl ether dimethacrylate (BisGMA) Silane treated silica Diurethanedimethacrylate (UDMA)	3M ESPE, USA

(Yellow Label Tea, Lipton, Turkey), coffee (Nescafe Classic, Nestle, Switzerland), and cola (Coca-Cola, USA). The nanohybrid composites were Nova Compo C (Imicryl, Turkey), RubyComp P (Rubydent, Turkey), Astor Plus (Dentac, Turkey), and Filtek Z550 (3M ESPE, USA). Composite specimens with a diameter of 8 mm and a thickness of 2 mm were produced using a cylindrical silicone mold. Resin composites were placed in the mold and compressed between two mylar strips and glass plates with slight hand pressure to extrude the excess material. The composites were placed and polymerized according to the manufacturer's instructions. A1 shade was used to standardize the color of each composite. Both the top and bottom of the composites were cured with the B-Cure Plus curing light (Woodpecker, China) for 20 seconds. A total of 160 samples were obtained, 40 from each composite (n=10). The samples were kept in distilled water at 37°C for 24 hours to complete their polymerization. The first shade measurement of the samples was carried out with a spectrophotometer device (VITA Easyshade Compact, VITA Zahnfabrik, Germany) according to the CIELAB (CIE Lab*) formula after drying with a paper towel.

Each composite resin was randomly divided into the following four solution groups: distilled water, cola (Coca-Cola Co, USA), tea (Yellow Label Tea, Lipton, Turkey), coffee (Nescafe Classic, Nestle, Switzerland). The tea was prepared by immersing a tea bag in 200 ml of distilled water boiled at 100 °C 5 to 10 times and resting for 3 minutes according to the manufacturer's instructions. According to manufacturer's instructions The coffee solution was made by adding 2 grams to 200 ml of distilled water that was boiled and left for 1 minute. Solutions were stored in sealed plastic containers.

The samples were kept in an oven at 37°C for 7 days in order to imitate the oral environment. Solutions were renewed every 24 hours for 7 days. Color measurements were carried out on the 1st, 3rd, and 7th days. Before each color measurement, the samples were washed with water for 10 seconds and dried with a paper towel. Spectrophotometer device was calibrated for each color measurement. The sample was measured 3 times and the average was taken and recorded. Measurements were performed under standard lighting on a white background. Color change values were calculated according to the formula $\Delta E = [(L1^* - L0^*)^2 + (a1^* - a0^*)^2 + (b1^* - b0^*)^2]^{1/2}$.

2.2. Statistical analysis

The Jamovi (Version 2.3.21) [ComputerSoftware], as accessed by https://www.jamovi.org, program was used for statistical analysis. Normality of data distribution was checked using the Shapiro–Wilk test. Due to normal distribution, Repeated Measure ANOVA was used for the color differences. Post-hoc comparisons were analysed with the Tukey's post hoc test (a = 0.05).

Table 2. Repeated Measure ANOVA test results regarding dental composites

Composite		Composite	Mean Difference	SE	p-value
Nova Compo C	-	Ruby Comp	0.11	0.25	0.969
Nova Compo C	-	AstorPlus	-1.42	0.25	**< 0.001**
Nova Compo C	-	Filtek Z550	-0.18	0.25	0.89
Ruby Comp	-	AstorPlus	-1.53	0.25	**< 0.001**
Ruby Comp	-	Filtek Z550	-0.29	0.25	0.648
AstorPlus	-	Filtek Z550	1.24	0.25	**< 0.001**

A post-hoc power analysis was conducted using the data from Table 2 to ensure the sample size was statistically sufficient. The analysis was performed using G*Power (Version 3.1.9.7, Heinrich-Heine-Universität Düsseldorf, Germany), calculating effect sizes from the mean differences and standard errors, with an alpha level of 0.05 and a sample size of 10 specimens per group. The average power across all comparisons was found to be 0.778, indicating high statistical power. This confirms that our sample size is adequate to detect significant differences in color stability among the composite materials tested, thus supporting the robustness of our findings.

3. Results

Nova Compo C, RubyComp P, and Filtek Z550 exhibited significantly higher color stability than Astor Plus ($p<0.001$). However, no significant difference was found between the other dental composites ($p>0.05$) (Table 2). Distilled water and cola caused significantly lower discoloration than tea and coffee ($p<0.05$); however, no significant difference was found between distilled water and cola ($p>0.05$) (Table 3). Color stability decreased significantly from day 1 to day 3 and from day 3 to day 7 ($p<0.001$) (Table 4). Marginal means plots were generated for dental composites (Fig. 1) and solutions (Fig. 2) depending on the periods.

4. Discussion

Mechanical properties of RBCs influence their clinical performance. In particular, the discoloration of the RBCs that developed over time is one of the most common reasons for replacing old restorations.[10] In this study, the color stability of three novel dental composites originating from Turkey was compared with Filtek Z550, which showed good color stability in previous studies, and their adequacy was evaluated.

The color stability of RBCs depends on the dimensions of the organic matrix filler particles, the depth of polymerization, and the colorants.[11] One of the exogenous causes of tooth discoloration is the dietary habits. These include tea, coffee, and nicotine. In this study, we used tea, coffee, and cola, which are commonly consumed daily, as staining solutions, which were evaluated in

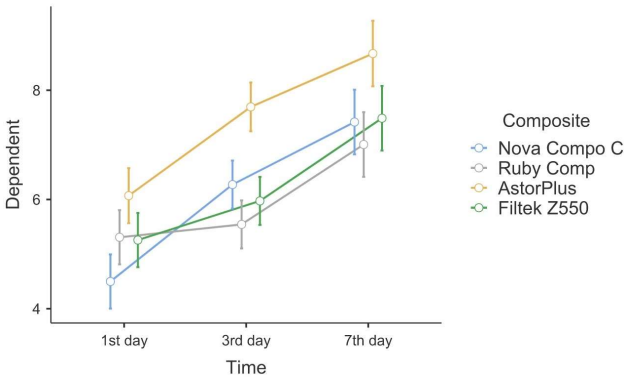

Fig. 1. Marginal means plots that were generated for dental composites

Table 3. Repeated Measure ANOVA test results regarding solutions

Solution		Solution	Mean Difference	SE	p-value
Distilled water	-	Cola	0.67	0.25	**0.036**
Distilled water	-	Tea	-4.85	0.25	**< 0.001**
Distilled water	-	Coffee	-10.54	0.25	**< 0.001**
Cola	-	Tea	-5.53	0.25	**< 0.001**
Cola	-	Coffee	-11.21	0.25	**< 0.001**
Tea	-	Coffee	-5.69	0.25	**< 0.001**

many studies. They indicated that the average daily coffee consumption is 3.2 cups and the average duration of consumption is 15 minutes.[12,13] The duration of 7 days was chosen to simulate the initial period of discoloration that occurs in clinical settings. According to previous studies[14,15], 24 hours of storage in a solution corresponds to one month of clinical exposure. Thus, a 7-day immersion period can simulate approximately seven months of daily beverage consumption. The 3-day duration was included to provide intermediate data points, offering insights into the progression of discoloration over time. This approach helps in understanding how discoloration evolves during the first week, which is often critical for clinical applications.

Previous studies on resin restorations reported that very smooth surfaces can be achieved when finishing with a matrix band. Although the surface roughness of the samples was not analyzed in this study, the samples were finished using transparent tape to standardize the finishing procedure. We preferred the Vita Easy Shade System as a color measuring device, since it offer the advantage of measuring the spectrum between 400-700 nm. While the human eye cannot detect values below 1.5, they can be measured with a spectrophotometer. ΔE values less than or equal to 3.3 are considered clinically detectable.[16] ΔE values above 3.3 have been reported to be clinically unacceptable and undesirable.[17]

The first null hypothesis of the study was rejected, and a difference was found between the RBCs in terms of color stability. Astor Plus showed lower performance in terms of color stability than other composites. The possible reason for this difference may be due to different mechanical properties, such as water absorption in composites.[18] Water absorption mainly occurs due to direct absorption in the resin matrix. The more the resin matrix is, the greater the water absorption.[19] Increased water absorption expands and plasticizes the organic matrix and hydrolyzes the silane. This may adversely affect the bonding of RBCs. The presence of microcracks in the resin matrix as a result of hygroscopic expansion and plasticizing effects, and the interfacial gaps formed between the filler and the resin matrix, cause staining and discoloration of the restoration.[20] Although the ratio of inorganic fillers in the resin matrix is close in all composites, the distribution of monomers in the resin matrix can affect color stability. UDMA monomer has been shown to be more resistant to color change than Bis-GMA.2 However, companies have not shared the percentages of monomers used. Consistent with previous studies[7-9], Filtek Z550 exhibited high color stability, probably due to mentioned intrinsic factors.

The second null hypothesis was rejected; coffee and tea caused more discoloration than other solutions. Many studies have shown that coffee causes more discoloration than other solutions.[21] The staining effect of coffee on composite resins may be related to RBCs being more susceptible to staining due to their water absorption properties. The absorption and adsorption of colorants by the organic phase has been described as the coloring mechanism of coffee. Tea and coffee contain yellow pigments of different polarities. Previous studies have also reported that coffee is more chromogenic than tea and cola, and coffee's yellow

Table 4. Repeated Measure ANOVA test results regarding time periods

Time		Time	Mean Difference	SE	p-value
1st day	-	3rd day	-1.09	0.14	**< 0.001**
1st day	-	7th day	-2.36	0.18	**< 0.001**
3rd day	-	7th day	-1.27	0.18	**< 0.001**

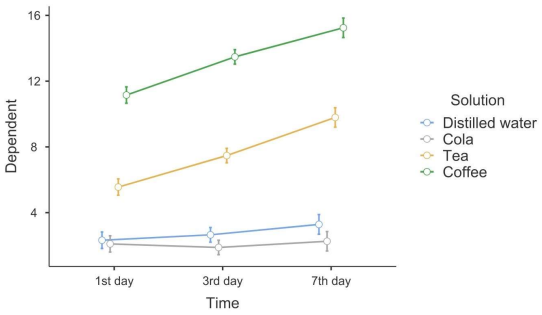

Fig. 2. Marginal means plots that were generated for solutions

pigments are less polar than tea. Although cola contains phosphoric acid, it does not show an intense coloration. Acids trigger the dissolution of materials and their erosive wear. There are also phosphate ions in Coca-Cola; these ions reduce the rate of dissolution of calcium phosphate, thereby suppressing the dissolution.

The third null hypothesis was rejected; The amount of discoloration increased as the waiting time of the samples in the solution increased. The analysis of immersion time alone revealed that the most noticeable discoloration occurred after 7 days. Irrespective of the type of solution used, findings revealed by previous studies, which showed that the longer staining periods increase discoloration, are consistent with the present study.

In this study, the color measurements of the dental composites were calculated based on the CIELAB (CIE Lab*) formula. The CIELAB formula is widely used and accepted in dental research for assessing color differences due to its ability to provide a comprehensive representation of color space. This choice allows for consistent comparison with previous studies that have also utilized the CIELAB system. However, it is important to acknowledge that the CIELAB formula has some limitations compared to the newer CIEDE2000 formula. The CIEDE2000 formula offers enhanced accuracy in measuring perceptual color differences, particularly in the areas of hue, chroma, and lightness.[22] It accounts for perceptual uniformity more effectively, which can be critical in certain dental applications where subtle color differences are significant.[23]

Additionally, color measurements in our study were performed under standardized lighting conditions on a white background. The selection of a white background was made to maintain consistency with the VITA Easyshade Compact device's calibration standards, which recommend a white background for optimal accuracy. Using a white background instead of a gray one provides higher contrast, enhancing the precision and reliability of the color measurements.[22] While gray backgrounds can minimize reflections and ambient light effects, the white background was deemed more appropriate for this study to ensure accurate calibration and measurement consistency.

Table 5. Color Change of Composite Materials in Different Solutions (1st, 3rd, and 7th Day)

Composite	Solution	1st day	3rd day	7th day
NC	Distilled water	2 ± 1.56	2.42 ± 0.72	3.4 ± 1.78
	Cola	2.3 ± 1.4	2.17 ± 1.03	2.58 ± 1.17
	Tea	4.62 ± 0.86	7.4 ± 1.54	9.98 ± 1.77
	Coffee	9.07 ± 2.02	13.1 ± 3.03	13.72 ± 4.03
RC	Distilled water	1.78 ± 1	1.43 ± 0.46	2.09 ± 1.17
	Cola	1.88 ± 1.12	1.27 ± 0.34	1.79 ± 0.58
	Tea	4.78 ± 1.04	7.12 ± 1.49	10.16 ± 2.07
	Coffee	12.79 ± 3.02	12.35 ± 1.63	13.98 ± 1.16
AP	Distilled water	2.43 ± 0.74	3.33 ± 0.55	3.26 ± 0.61
	Cola	1.19 ± 0.76	1.23 ± 0.91	1.26 ± 0.76
	Tea	7.2 ± 1.33	8.4 ± 1.18	10.48 ± 1.29
	Coffee	13.45 ± 1.95	17.82 ± 1.37	19.68 ± 1.7
FZ	Distilled water	3.07 ± 2.09	3.42 ± 1.92	4.39 ± 2.46
	Cola	3.03 ± 1.9	2.87 ± 1.56	3.41 ± 1.64
	Tea	5.63 ± 1.01	6.96 ± 1.14	8.55 ± 1.75
	Coffee	9.3 ± 1.66	10.64 ± 1.15	13.61 ± 2.91

NC: Nova Compo C, RC: RubyComp P, AP: Astor Plus, FZ: Filtek Z550

This study was conducted in vitro, which does not entirely replicate the oral environment. Future studies should consider in vivo conditions to better understand the real-world applicability of these findings. Additionally, the flat surface preparation of specimens in this study may not fully represent the complex surface morphology of actual dental restorations. The sample size, although sufficient for this study, could be expanded in future research to validate these findings more robustly. Polishing was not applied to the samples. Instead, to standardize the surface finish, all specimens were prepared using a transparent tape. This method ensured a consistent and smooth surface across all samples, which is essential for accurately assessing color stability without the variability that different polishing techniques might introduce. However, we acknowledge that this approach may limit the study's ability to fully replicate clinical conditions. In a clinical setting, polishing can enhance surface smoothness and potentially improve the color stability of composites. Therefore, the lack of polishing in this study is a limitation that should be considered when interpreting the results.

5. Conclusion

In conclusion, our study found that beverages such as coffee and tea cause significantly more discoloration in dental composites than distilled water and cola. The newly introduced Turkish composites demonstrated similar color stability to the well-established Filtek Z550, except for Astor Plus, which showed lower color stability. These findings have important clinical implications, suggesting that dental practitioners should consider patients' dietary habits when selecting composite materials to ensure long-term aesthetic outcomes. Composites like Nova Compo C and RubyComp P, which showed higher color stability, may be more suitable for patients who frequently consume staining beverages. Future research should focus on long-term clinical trials to confirm these in vitro results and explore new composite formulations with enhanced stain resistance to further improve patient care.

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Original Article

Prevalence of Dens Invaginatus in Maxillary Lateral Teeth and Its Association with Periapical Lesions: A Cone-Beam Computed Tomography

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CLINICAL SIGNIFICANCE

DI is a common developmental anomaly. Accurate assessment of periapical lesions and DI prevalence in maxillary lateral teeth is crucial for diagnosis and treatment planning, enabling clinicians to tailor interventions based on DI subtypes and their associations.

ABSTRACT

Objectives: This study aimed to determine the prevalence of Dens Invaginatus (DI) and examine the association between factors such as age, gender, and DI type with the occurrence of periapical lesions.

Materials and Methods: Cone beam computed tomography (CBCT) images of 250 patients were evaluated. The relationship between gender, tooth number, DI type according to Oehler classification, and periapical lesions (PL) was examined. PL were grouped using Estrela's CBCT Periapical Index (CBCT PAI). Periapical lesion incidence rates were statistically compared using chi-square tests and descriptive statistics. The statistical analysis was performed using SPSS v27.0 software.

Results: 250 CBCT volumes were examined. The study involved 32 patients (average age 29.15 ± 11.50 years). DI was found in 10.0% of maxillary lateral teeth (11.6% right, 8.4% left) with no significant gender or age group differences ($p>0.05$). Type I DI was most common in the 15-20 age group. Most teeth had a CBCT PAI=0, with no significant differences across age groups ($p>0.05$). However, for the right lateral tooth, Type II DI was significantly associated with higher CBCT PAI scores ($p<0.05$), whereas no significant difference was found for the left lateral tooth ($p=0.142$).

Conclusion: DI is a developmental dental anomaly that is relatively prevalent. The presence of associated periapical lesions and the proportion of maxillary lateral teeth impacted by DI should be meticulously assessed during the diagnosis and treatment planning process. Clinicians can more effectively plan and execute treatment by comprehending the prevalence of DI, its subtypes, and their relationship to periapical lesions.

1. Introduction

Dens invaginatus (DI), also referred to as "dens in dente," is a developmental dental anomaly in which enamel and dentin invaginate into the dental papilla prior to the calcification of the dental tissues.[1] The depth of the invagination varies from superficial cases, where only the crown is affected and the cingulum pit is slightly prominent, to deep folds extending to the apex, affecting both the crown and the root. Coronal DI is more common, with a reported prevalence ranging from 0.04% to 12% in all patients.[2-8] The central incisors, premolars, canines, and molars are the teeth most frequently affected, followed by the maxillary permanent lateral incisors. This condition is uncommon in primary teeth and frequently effects both sides. The precise etiology of this developmental anomaly is still uncertain.[9,10]

DI can lead to early tooth decay and predisposition to pulpitis, with advanced stages potentially resulting in periodontal inflammation and pulp necrosis.[10,11] Coronal DI is classified into three primary categories. Type I is characterized by a protrusion that remains above the cemento-enamel junction. Type II extends past the cemento-enamel junction and terminates in a closed pouch, which may or may not have a connection with the pulp. Type III penetrates the root and exits through the apical or lateral radicular region, leaving the pulp unconnected. Type III is further categorized into two distinct subcategories. In Type IIIa, the inward folding of tissue is linked to the periodontal ligament through a pseudo-foramen. In Type IIIb, it establishes communication with the periodontal ligament through the apical foramen. Radicular dens invaginatus, a condition that is less prevalent, is thought to be the consequence of the Hertwig's epithelial root sheath's proliferation, which results in an enamel strip along the root surface. Radiographically, the affected teeth demonstrate root enlargement with an enamel-covered invagination, with the invagination's aperture situated laterally on the root.[9]

Three-dimensional (3D) cone beam computed tomography (CBCT) offers significant advantages over traditional two-dimensional (2D) radiographs in the examination of root canal anatomy and periapical pathologies. In conventional 2D imaging techniques, anatomical structures can overlap, which can make diagnosis particularly challenging in complex cases. CBCT provides high-resolution volumetric images that deliver detailed insights into the morphology of teeth, enhancing the accuracy of diagnosing developmental anomalies such as DI. This technology allows for a thorough examination of the invagination process, not only in cases where the crown is affected but also in those where the root is involved, thereby increasing diagnostic precision.[12,13]

The literature discusses different treatment options for managing DI, ranging from non-surgical endodontic treatments to regenerative endodontic procedures, depending on the type and severity of the condition. Early diagnosis of DI is crucial for initiating prophylactic treatment and preventing complications like pulpal necrosis. The removal of lumen contents and any decayed dentin is necessary for larger invaginations. Subsequently, a calcium hydroxide base is applied to manage micro-connections with adjacent pulp canals. The use of calcium hydroxide or mineral trioxide aggregate for apexification is generally efficacious in teeth with open apices, resulting in a permanent restoration.[9] Three-dimensional imaging techniques have also improved the diagnosis and treatment planning for teeth with complex root canal systems, including those affected by DI. In conclusion, while previous studies have provided insights into various treatment modalities for DI and associated periapical lesions, this study aimed to establish the frequency of DI and investigate how factors like age, gender, and DI type are linked to the occurrence of periapical

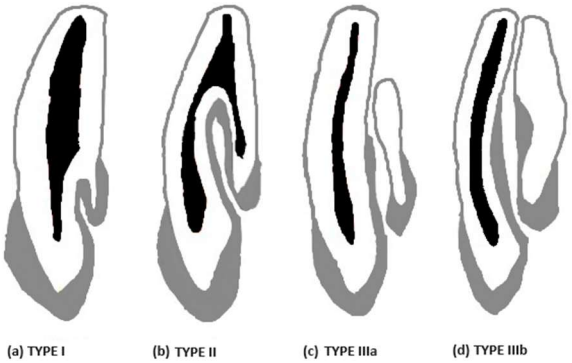

Fig. 1. Classification of dens invaginatus according to Oehlers. Type I (a), type II (b), type IIIa (c) and type IIIb (d).

lesions. The study also aimed to assess the periapical status relative to different DI types.

2. Materials and Methods

2.1. Ethical approval and sample size

The study protocol received approval from the Research Ethics Committee of the Faculty of Dentistry at Necmettin Erbakan University for Non-Pharmaceutical and Medical Device Research (approval no. 2022/169).

Using the G-power 3.1.9.4 software, the required study population was calculated to be at least 43 individuals, based on a 95% confidence level, α=0.05, and a power (1-β) of 0.95, for detecting differences between two independent proportions.[4]

2.2. Study population and selection criteria

This retrospective study examined CBCT images acquired from patients who visited the oral and maxillofacial radiology clinic in the university for diagnostic purposes between 2022 and 2024. The study population consisted of individuals aged between 15 and 64 years (125 female, 125 male), as CBCT records of individuals outside this age range were excluded due to avoid potential biases related to age-related developmental and degenerative changes in dental structures that could impact the accuracy of the study outcomes.

The inclusion criteria required artifact-free images with optimal quality, obtained with an imaging volume of 60x60 mm, 100x100 mm, 140x100 mm, or 170x120 mm, which allowed for full visualization of both lateral teeth. Only scans that met these criteria and allowed for accurate assessment of DI and PLs were included. Images with low resolution, those showing only edentulous areas, or those featuring primary teeth were excluded from the study to maintain the accuracy and consistency of the analysis.

Fig. 2. From left to right, sagittal and axial views of CBCT scans showing A) Type I and B) Type II classifications.

2.3. DI and periapical lesion assessment

All maxillary lateral teeth were classified according to Oehler's DI classification into types I, II, IIIa, and IIIb.[14] Illustrative examples of the DI types are presented in Fig. 1, while corresponding CBCT imaging examples are shown in Fig. 2.

CBCT was employed to evaluate periapical lesions using the following cone beam computed tomography periapical index (CBCT PAI) criteria[15]:

0: Periapical bone structures that are intact;
1: Periapical radiolucency diameters exceeding 0.5–1 mm;
2: The periapical radiolucency diameter exceeds one to two millimeters.
3: Periapical radiolucency diameter exceeding 2–4 millimeters;
4. The periapical radiolucency diameter exceeds 4–8 mm.
5. The diameter of the periapical radiolucency exceeds 8 mm

Scans were analyzed in both sagittal and axial views on a 27" monitor with a resolution of 1920 × 1080 pixels (DellSE2722H; Dell Inc., Round Rock, TX) under consistent illumination conditions. Age, gender, the presence or absence of DI, and the presence or absence of periapical lesions were documented following the CBCT assessment.

All evaluations were assessed by a three-year experienced radiologist (AHS). To assess intra-observer agreement, measurements were repeated after three weeks, blinded to the first measurements. According to the Kappa analysis, a Kappa value of 0.921 for DI and 0.893 for PAI was observed, indicating excellent agreement for both measures.

2.4. Statistical analysis

SPSS 25.0 (IBM, Chicago, IL, USA) was implemented to execute the statistical data analysis. Descriptive statistics were calculated using frequency and percentages. The chi-square test was employed to analyze the data, with a significance level of 0.05.

3. Results

The average age of individuals included in this study was 29.15 ± 11.50 years. The distribution of age groups by gender was homogeneous, with no statistically significant difference (p>0.05) (Table 1).

For the maxillary lateral teeth, DI was detected in 50 out of 500 teeth (10.0%). Of these cases, 29 were found on the right side (11.6%) and 21 on the left side (8.4%). The overall incidence of bilateral DI was higher (78%) compared to unilateral DI (32%). In females, 89.6% of the right lateral teeth showed no DI, while 9.6% had Type I and 0.8% had Type II. On the left side, these percentages were 93.6% and 6.4%, respectively (Table 2). In males,

Table 1. Distribution of age groups according to gender

Age groups	Gender		Total	p value
	Female	Male		
15-20 years	27	37	64	
21-26 years	35	23	58	
27-32 years	22	21	43	
33-38 years	21	15	36	0.152
39-44 years	11	11	22	
45 years and older	9	18	27	
Total	125	125	250	

Table 2. Distribution of dens ınvaginatus presence in maxillary right and left lateral teeth by gender and age groups

	Dens Invaginatus Presence											
	Maxillary Right Lateral Tooth						Maxillary Left Lateral Tooth					
	None	Type I	Type II	Type IIIa	Type IIIb	p value	None	Type I	Type II	Type IIIa	Type IIIb	pvalue
Gender												
Female	112 (89.6%)	12 (9.6%)	1 (0.8%)	0 (0.0%)	0 (0.0%)	0.840	117 (93.6%)	8 (6.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.370
Male	109 (87.2%)	15 (12.0%)	1 (0.8%)	0 (0.0%)	0 (0.0%)		112 (89.6%)	12 (9.6%)	1 (0.8%)	0 (0.0%)	0 (0.0%)	
Age Groups												
15-20 years	52 (81.3%)	10 (15.6%)	2 (3.1%)	0 (0.0%)	0 (0.0%)		56 (87.5%)	7 (10.9%)	1 (1.6%)	0 (0.0%)	0 (0.0%)	
21-26 years	52 (89.7%)	6 (10.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		53 (91.4%)	5 (8.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
27-32 years	39 (90.7%)	4 (9.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		39 (90.7%)	4 (9.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
33-38 years	33 (91.7%)	3 (8.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.795	33 (91.7%)	3 (8.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.794
39-44 years	21 (95.5%)	1 (4.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		22 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
45 years and older	24 (88.9%)	3 (11.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		26 (96.3%)	1 (3.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	

For the maxillary lateral teeth, DI was detected in 50 out of 500 teeth (10.0%). Of these cases, 29 were found on the right side (11.6%) and 21 on the left side (8.4%). The overall incidence of bilateral DI was higher (78%) compared to unilateral DI (32%). In females, 89.6% of the right lateral teeth showed no DI, while 9.6% had Type I and 0.8% had Type II. On the left side, these percentages were 93.6% and 6.4%, respectively. In males, 87.2% of the right lateral teeth showed no DI, while 12% had Type I and 0.8% had Type II. On the left side, these percentages were 89.6%, 9.6%, and 0.8%, respectively. Across all age groups, the prevalence of DI ranged from 81.3% to 95.5%. Type I DI was more common in the 15-20 age group for both teeth (15.6% on the right; 10.9% on the left). The p-values indicate that the differences between the groups were not statistically significant for either tooth based on gender and age groups (Table 2).

In terms of the CBCT PAI, for the maxillary right lateral tooth, 95.2% of females had a CBCT PAI=0, 4.0% had a CBCT PAI=1, and 0.8% had a CBCT PAI=4. Among males, 42.8% had a CBCT PAI=0, 4.8% had a CBCT PAI=1, 1.6% had a CBCT PAI=2, and 0.8% had a CBCT PAI=4 (Table 3). For the maxillary left lateral tooth, 98.4% of females had a CBCT PAI=0, and 0.8% had both a CBCT PAI=1 and CBCT PAI=2. Among males, 95.2% had a CBCT PI=0, 3.2% had a CBCT PAI=1, and 1.6% had a CBCT PAI=2 (Table 3). The p-values indicate that the differences between the groups for both teeth were not statistically significant (Table 3). Across all age groups, the majority of both teeth exhibited a PI=0 (Table 3). Following this, the highest PI=1 rate was found in the 15-20 age group (maxillary right lateral 12.5%; maxillary left lateral 6.3%) (Table 3). The distribution of PI rates among age groups was not statistically significant ($p>0.05$) (Table 3).

For the maxillary right lateral tooth, 88.9% of Tip I DI cases had a PAI=0, while 50.0% of Tip II cases had a higher occurrence of CBCT PAI=4. These differences were statistically significant ($p<0.05$) (Table 4). For the maxillary left lateral tooth, 90% of Tip I DI cases had a PAI=0, while 100% of Tip II cases had a CBCT PAI=1. However, these differences were not statistically significant ($p=0.142$) (Table 4).

4. Discussion

The anatomical complexity is closely associated with the extent of invagination in DI, particularly in type III.[4] Consequently, CBCT is an invaluable tool for diagnosing DI [16], as it offers a comprehensive understanding of the dental anatomy of complex DI, including the presence of varying degrees of invagination. Endodontic treatment planning that is predicated on inadequate anatomical information may result in deviations from the root canal trajectory, as the delicate enamel of teeth affected by DI is more susceptible to pulpal infection as a result of dehiscence.[2] The objective of this investigation was to assess the prevalence and morphological characteristics of DI using CBCT, as it is frequently linked to endodontic and/or peri-radicular diseases.

CBCT provides significant advantages in identifying DI and deciding on its treatment. The characteristics and extent of invagination may not be fully determined with panoramic and periapical radiographs.[17] CBCT images, however, have been utilized in numerous studies for diagnosing DI as they allow for a precise examination of tooth morphology.[4,7,17-19] One limitation of traditional radiographic classification is its dependence on two-dimensional images, which suffer from structural superimposition.[20] On the other hand, high-resolution CBCT generates volumetric images that furnish comprehensive details regarding the apex features, the presence and dimensions of periapical lesions, the type and extent of invagination, and the relationship with the root canal. These details are instrumental in the planning of treatment.[4,7,16,17,21-23] Within the crown (the enamel lining the invagination), invaginations can seem like pouches with hypodense or hyperdense borders; in DI cases, they can even extend to the root.[24]

The prevalence of each type of DI was estimated in numerous included studies using the Oehlers classification. The prevalence of teeth with DI has been observed to vary between 0.04 and 12%.[2-8] The most prevalent type was type I, followed by type II and type IIIab, as determined by a systematic review and meta-analysis.[18] The overall prevalence of DI was determined to be 10.0% in this study, with type I at 94.0% and type II at 6.0%. This is in contrast to the results of Mabrouk et al.[21] and Hegde et al.[7], which reported that type II was the most prevalent, with prevalences of 47.61% and 61.03%, respectively. The prevalence of DI types was previously ascertained using Oehler's classification. Çakıcı et al.[25] and Gündüz et al.[6] determined that type I DI had the highest rate (69.8-93.8%), followed by type II (3.1-26.6%) and type III (3-12.5%). The prevalence and characteristics of DI vary significantly across different geographic regions, which highlights the importance of

Table 3. Distribution of Periapical Index in Maxillary Right and Left Lateral Teeth by Gender and Age Groups

	Periapical Index											
	Maxillary Right Lateral Tooth						Maxillary Left Lateral Tooth					
	0	1	2	3	4	p value	0	1	2	3	4	p value
Gender												
Female	119 (95.2%)	5 (4.0%)	0 (0.0%)	0 (0.0%)	1 (0.8%)	0.686	123 (98.4%)	1 (0.8%)	1 (0.8%)	0 (0.0%)	0 (0.0%)	0.411
Male	116 (92.8%)	6 (4.8%)	2 (1.6%)	0 (0.0%)	1 (0.8%)		119 (95.2%)	4 (3.2%)	2 (1.6%)	0 (0.0%)	0 (0.0%)	
Age Groups												
15-20 years	54 (84.4%)	8 (12.5%)	1 (1.6%)	0 (0.0%)	1 (1.6%)		58 (90.6%)	4 (6.3%)	2 (3.1%)	0 (0.0%)	0 (0.0%)	
21-26 years	58 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		58 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
27-32 years	41 (95.3%)	2 (4.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		41 (95.3%)	1 (2.3%)	1 (2.3%)	0 (0.0%)	0 (0.0%)	
33-38 years	34 (94.4%)	1 (2.8%)	1 (2.8%)	0 (0.0%)	0 (0.0%)	0.056	36 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.325
39-44 years	21 (95.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.5%)		22 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
45 years and older	27 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		27 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	

Table 4 Distribution of Periapical Index by Dens Invaginatus Types in Maxillary Right and Left Lateral Teeth

Type of Dens Invaginatus	Periapical Index				p value
	Maxillary Right Lateral Tooth				
	0	1	2	4	
Type I	24 (100.0%)[a]	3 (75.0%)[a]	0 (0.0%)[a]	0 (0.0%)[a]	0.011*
Type II	0 (0.0%)[b]	1 (25.0%)[b]	0 (0.0%)[b]	1 (100.0%)[b]	
Type of Dens Invaginatus	**Periapical Index**				**p value**
	Maxillary Left Lateral Tooth				
	0	**1**	**2**	**4**	
Type I	18 (90.0%)	1 (5.0%)	1 (5.0%)	0 (0.0%)	0.142
Type II	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	

*p<0.05 Each same superscript letter indicates a subset of right carotid artery calcification categories whose column ratios are not significantly different from each other at the .05 level.

which highlights the importance of conducting research in these areas. Location-specific differences appear to be quite common.[7]

The overall incidence of bilateral DI was higher (78%) in our study than unilateral DI (32%). Studies that have reported prevalent bilateral occurrence in 82.0% [21] and 67.5% [7] of cases are consistent with these findings. Furthermore, Yalcın et al. [26], Capar et al. [17], and Rozylo et al.[27] determined that the frequency of bilateral occurrence of DI was 24.48%, 31.3%, and 24.2%, respectively. CBCT images were the subject of analysis in all of these investigations.

In this study, no significant difference was observed in terms of the prevalence of DI in the right and left maxillary lateral teeth according to gender (p = 0.840 and p = 0.370). Some previous studies also support this finding.[7,19,25,28,29] This finding suggests that the occurrence of DI is not influenced by gender, supporting the notion that DI is a developmental anomaly that arises independently of gender-related factors.[30]

In other studies, no significant differences were observed between age groups in terms of the presence or absence of DI.[31,32] In a study conducted in 2024 in a Turkish population [33], the presence of DI was found to be higher in the 20-30 age group, but no statistically significant difference was also found. The current study also supports these findings. This suggests that the occurrence of DI does not seem to vary significantly across different age groups, indicating that age may not be a major factor influencing the development of this anomaly. The likely reason is that this anomaly occurs during tooth development and is not influenced by factors that change with age. DI is a developmental anomaly that arises during the embryonic stages of tooth formation, meaning that once the tooth development is complete, the presence of DI is established and remains unchanged throughout life. Since DI is determined during the early stages of tooth formation, it does not fluctuate as a person age.[34,35]

Bacterial accumulation in the form of biofilm within the invaginated area can impact the pulp and potentially lead to necrosis. This increases the risk of pulp disease in teeth with DI, which may result in pulp necrosis and subsequent periapical pathology.[9] By using the CBCT PAI index to classify and score DI-related periradicular lesions, we were able to correlate different DI subtypes with the progression of periradicular disease. In our study, type I DI was linked to the absence of periapical lesions, while type II DI was associated with the presence of periapical lesions in the right lateral teeth, with a significant difference noted between the two (p=0.011). Similarly, Çapar et al.[17] found that type I DI was generally not accompanied by periapical lesions, whereas type II DI had a 25% incidence of periapical lesions, and in type III DI, periapical lesions were present in all cases.

In this study, we investigated the prevalence of DI and the relationship between DI types and periapical lesions in a Turkish subpopulation. CBCT imaging, which is more effective than two-dimensional periapical radiographs in classifying DI types and detecting periapical lesions [15], was utilized to enhance diagnostic accuracy. While the use of CBCT provided a distinct advantage, it is important to note that its indications are generally more restricted compared to conventional imaging techniques and do not typically include dental anomalies such as DI. To mitigate this limitation, we analyzed 250 CBCT images obtained for various clinical reasons, allowing us to examine a substantial number of teeth. Notably, among the 25 teeth affected by DI, lesions were detected in only 15 cases, underscoring the need for cautious interpretation of the findings, particularly in light of the relatively small sample size and the limited number of periapical lesions observed. Additionally, a limitation of the study is that it was conducted with a single observer, which may introduce observer bias. Although our results are consistent with those of previous studies, expanding the sample size, including data from diverse populations, and involving multiple observers would strengthen the validity and generalizability of the findings.

5. Conclusion

The prevalence of dental invagination (DI) in maxillary lateral teeth was 10.0% within the constraints of the current study. The incidence of DI was higher on the right side (11.6%) compared to the left side (8.4%), indicating that there was not a statistically significant distinction between the left and right arches. Type I DI was more prevalent in the 15-20 age group, but there were no statistically significant differences in DI prevalence based on gender or age. Specifically, Type I DI was predominantly associated with a PAI of 0, indicating an absence of periapical lesions, whereas Type II DI showed a significant association with higher PAI scores, particularly in the maxillary right lateral teeth, reflecting the presence of periapical pathology. These findings underscore the utility of CBCT in providing detailed insights into the anatomical variations of DI and their clinical implications. Further research in diverse populations is recommended to better understand regional differences in DI prevalence and the association between DI types and periapical outcomes.

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Original Article

Current State, Pioneering Studies and Future Trends in Orthodontic bonding: A Bibliometric Analysis

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CLINICAL SIGNIFICANCE

This bibliometric analysis offers crucial insights into the evolving trends and key contributors in orthodontic bonding research, providing a foundation for future studies aimed

ABSTRACT

Objectives: Orthodontic bonding plays a crucial role in the effectiveness of orthodontic treatment. This study aims to perform a bibliometric analysis of research in this field, identifying key contributors, influential studies, and emerging trends.

Materials and methods: A systematic search was conducted in the Web of Science (WoS) database for articles published between 1981 and 2023 using specific orthodontic bonding-related keywords. From 1,856 articles retrieved, 1,497 met the inclusion criteria. Bibliometric analyses were performed using VOSviewer software, focusing on co-authorship, co-occurrence, and citation patterns. The analysis evaluated the productivity of authors, institutions, countries, and journals and mapped frequently used keywords.

Results: The USA emerged as the leading country in publications and citations, followed by Turkey and Brazil. The University of Iowa was identified as the most productive institution. Samir E. Bishara was the most prolific and cited author. The study revealed a growing focus on topics such as shear bond strength, self-etch primers, and antimicrobial adhesives. The American Journal of Orthodontics and Dentofacial Orthopedics was the most influential journal, with the highest number of key publications.

Conclusion: This bibliometric analysis provides valuable insights into the orthodontic bonding literature, highlighting significant contributions and trends. Although limited to WoS and English-language publications, the study offers a comprehensive perspective on the field's development and suggests potential areas for future research.

1. Introduction

The most popular bonding system in orthodontics and restorative treatment is based on the micromechanical bond of resin composite materials to the enamel surface.[1] Direct bonding of orthodontic brackets to the tooth surface with composite resin and acid etching is widely used.[2,3] Orthodontic adhesives play a crucial role in the success of orthodontic treatments, as they are responsible for securely bonding orthodontic attachments, such as brackets, to the enamel surface of teeth. The effectiveness of these adhesives directly influences the stability of the orthodontic appliances and, consequently, the overall treatment outcome. Given their importance, a significant amount of research has been devoted to improving the bonding strength, durability, and biocompatibility of these adhesives. Studies in this area have explored various types of adhesives, surface preparation techniques, and the effects of different bonding agents on both the mechanical properties and the long-term health of the tooth enamel. As orthodontic treatment evolves with new materials and techniques, understanding the developments in adhesive technology becomes essential for optimizing patient outcomes.

Literature reviews are meant to examine the general state of any research area. It is important to collect, and categorize existing knowledge in the research area and identify gaps.[4] Bibliometric analysis is a systemic analysis that evaluates the literature using mathematical and statistical methods.[5–7] Traditional literature reviews investigate a smaller and homogeneous area in depth. With bibliometric research, large fields of study can be assessed.[4] The overall structure of the study area is assessed superficially and quantitatively.[4,5,8] Bibliometric analyses are used to evaluate the development of the literature of the relevant field over time. The performance of scientific elements (study, journal, keyword, author, country, institution) is measured. It evaluates the effectiveness and productivity of researchers, institutions, journals, and countries by using bibliometric indicators and making Visualizations.[5,8–11]

Bibliometric analysis became widespread in the field of dentistry too.[5,7,11–14] Orthodontic bonding is not only foundational to the success of orthodontic treatments but also directly impacts patient outcomes, from treatment efficiency to enamel preservation. Given the rapid development of new adhesive materials and techniques, it is essential to systematically analyze existing research to identify the most influential studies, leading authors, and emerging trends. Therefore, the aim of this study is to conduct a comprehensive bibliometric analysis of the orthodontic bonding literature, thereby providing valuable insights into the field's evolution, current state, and future directions.

2. Materials and Methods

2.1. Research methodology

This study was designed to conduct a bibliometric analysis of the orthodontic bonding literature. The Web of Science (WoS) database was selected as the primary data source due to its extensive coverage and reliability in providing comprehensive bibliometric data. The search was conducted on June 5, 2024, and was limited to articles published up until December 2023 to ensure a consistent and complete dataset. The search terms were used to find studies most relevant to the orthodontic bonding area. To enhance the precision of the search, the topic field was restricted to the keywords, abstract and title. The search was conducted as follows: Topic = (''orthodontic bonding and self-etch primer'') OR Topic = (''orthodontic bonding'' and ''self-etch bond system'') OR Topic = (''orthodontic bonding'' and ''etch-and-rinse'') OR Topic = (''orthodontic bonding'' and ''total-etch'') OR Topic = (''orthodontic bonding'' and ''phosphoric acid etching'') OR Topic = (''orthodontic bonding'' and ''conventional acid-etch technique'') OR Topic = (''orthodontic bonding adhesive'') OR Topic = (''orthodontic bonding'' and ''adhesive composite resin'').

2.2. Inclusion criteria

A total of 1,856 articles were retrieved from the database, and after applying inclusion criteria—such as relevance to the topic, language (English), and publication type (article, review, proceeding paper)—1,497 articles were deemed suitable for the bibliometric analysis.

2.3. Data analysis and visualization

Data analysis was performed using VOSviewer (version 1.6.14; Center for Science and Technology Studies, Leiden University) and Excel (Microsoft Office 2016). VOSviewer was used to apply bibliometric analysis techniques and design maps. The unit of analysis under study is symbolized by circles. The position of the circles relative to each other indicates similarity and relatedness. Relationship/ collaboration is represented by the lines between the circles. The meaning of circle colors varies according to the type of visualization. It is explained in detail in the figure descriptions. WoS functions (citation reports, analysis results) were also used for data analysis.

The bibliometric analysis involved several key techniques: Co-authorship analysis was performed to assess collaborative efforts among authors, institutions, and countries. This analysis helps to identify the networks and partnerships that contribute to research productivity in the field of orthodontic bonding. Co-occurrence analysis focused on the frequency and relationships of key terms m and concepts found within the titles, abstracts, and keywords of the articles. This analysis highlights the central themes and topics that have emerged in the literature over time. Citation analysis was conducted to determine the impact of specific studies, authors, institutions, and countries by analyzing the number of citations they received. This method provides insight into the most influential contributors to the field.

The Hirsch h-index is defined as the number of articles with a citation counts ≥ h and it is a useful index for assessing the scientific impact and productivity of journals and authors. The index (h-index) was obtained from the bibliometric data provided by WoS in the present study.

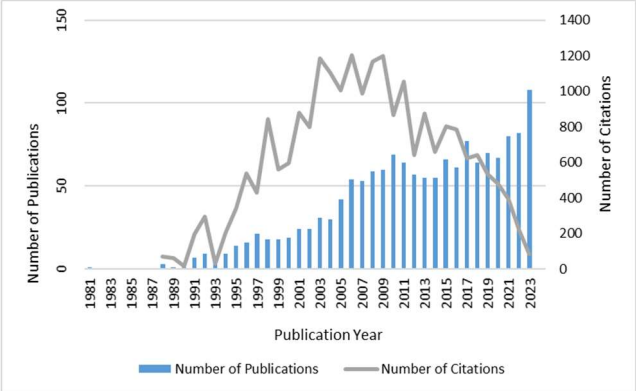

Fig 1. Total number of publications and total number of citations by publication year

Table 1. Information of the 20 most cited articles.

Title	Authors	Journal	Publication Year	Total Citations	Average per Year
1. Experimental antimicrobial orthodontic adhesives using nanofillers and silver nanoparticles	Ahn, SJ; Lee, SJ; Kook, JK; Lim, BS	Dental Materials	2009	203	12.63
2. Effect of a self-etch primer/adhesive on the shear bond strength of orthodontic brackets	Bishara, SE; VonWald, L; Laffoon, JF; Warren JJ	American Journal of Orthodontics And Dentofacial Orthopedics	2001	195	8.13
3. The use of bovine enamel in bonding studies	Oesterle, LJ; Shellhart, WC ; Belanger, GK	American Journal of Orthodontics And Dentofacial Orthopedics	1998	151	5.59
4. A comparison of shear bond strength and debonding characteristics of conventional, moisture-insensitive, and self-etching primers in vitro	Rajagopal, R; Padmanabhan, S; Gnanamani, J	Angle Orthodontist	2004	139	6.62
5. Enamel loss during bonding, debonding, and cleanup with use of a self-etching primer	Hosein, I; Sherriff, M; Ireland, AJ	American Journal of Orthodontics And Dentofacial Orthopedics	2004	131	6.24
6. Influence of surface roughness on streptococcal adhesion forces to composite resins	Mei, L; Busscher, HJ; van der Mei, HC; Ren, YJ	Dental Materials	2011	125	8.93
7. The inappropriateness of conventional orthodontic bond strength assessment protocols	Eliades, T; Brantley, WA	European Journal of Orthodontics	2000	117	4.68
8. Surface preparation for orthodontic bonding to porcelain	Zachrisson,YO; Zachrisson, BU; Buyukyilmaz, T	American Journal of Orthodontics And Dentofacial Orthopedics	1996	111	3.83
9. Laser etching of enamel for direct bonding with an Er,Cr:YSGG hydrokinetic laser system	Üsümez, S; Orhan, M; Üsümez, A	American Journal of Orthodontics And Dentofacial Orthopedics	2002	101	4.39
10. Effect of water and saliva contamination on shear bond strength of brackets bonded with conventional, hydrophilic, and self-etching primers	Cacciafesta, V; Sfondrini, MF; De Angelis, M; Scribante, A; Klersy, C	American Journal of Orthodontics And Dentofacial Orthopedics	2003	97	4.41
11. Effect of an acidic primer on shear bond strength of orthodontic brackets	Bishara, SE; Gordan, VV; VonWald, L; Olson, ME	American Journal of Orthodontics And Dentofacial Orthopedics	1998	97	3.59
12. Shear bond strength and antibacterial effects of orthodontic composite containing TiO2 nanoparticles	Poosti, M; Ramazanzadeh, B; Zebarjad, M; Javadzadeh, P; et al.	European Journal of Orthodontics	2013	94	7.83
13. Effect of self-etching primers on bond strength - Are they reliable?	Buyukyilmaz, T; Usumez, S; Karaman, AI	Angle Orthodontist	2003	93	4.23
14. Shear bond strength of composite, glass ionomer and acidic primer adhesive systems	Bishara, SE; Gordan, VV; VonWald, L; Jakobsen, JR	American Journal of Orthodontics And Dentofacial Orthopedics	199	90	3.46
15. Depth of resin penetration into enamel with 3 types of enamel conditioning methods: A confocal microscopic study	Kumar, KRR; Sundari, KKS; Venkatesan, A; Chandrasekar, S	American Journal of Orthodontics And Dentofacial Orthopedics	211	88	6.29
16. Biomimetic Effect of Nano-Hydroxyapatite in Demineralized Enamel before Orthodontic Bonding of Brackets and Attachments: Visual, Adhesion Strength, and Hardness in In Vitro Tests	Scribante, A; Farahani, MRD; Marino, G; Matera, C; Baena, RRY; Lanteri, V; Butera, A	Biomed Research International	2020	85	17
17. Effect of using self-etching primer for bonding orthodontic brackets	Yamada, R; Hayakawa, T; Kasai, K	Angle Orthodontist	2002	80	3.48
18. Rapid curing of bonding composite with a xenon plasma arc light	Oesterle, LJ; Newman, SM; Shellhart, WC	American Journal of Orthodontics And Dentofacial Orthopedics	2001	76	3.17
19. Comparison of bond strength of three adhesives: Composite resin, hybrid GIC, and glass-filled GIC	Rix, D; Foley, TF; Mamandras, A	American Journal of Orthodontics And Dentofacial Orthopedics	2001	76	3.17
20. Porcelain surface treatment by laser for bracket-porcelain bonding	Akova, T; Yoldas, O; Toroglu, MS; Uysal, H	American Journal of Orthodontics And Dentofacial Orthopedics	2005	74	3.7

Table 2. The 10 most productive authors

Authors	Institution	Country	No of Publications
Bishara, Samir E.	University of Iowa	USA	51
Eliades, Theodore	University of Zurich	Switzerland	35
Uysal, Tancan	Izmir Katip Celebi University	Turkey	33
Laffoon, John F.	University of Iowa	USA	32
Francesca, Sfondrini Maria	University of Pavia	Italy	28
Scribante, Andrea	University of Pavia	Italy	27
Warren, John J.	University of Iowa	USA	23
Millett, Declan T.	Un. College Cork	Ireland	22
Eliades George	University of Athens	Greece	22
Vicente, Ascension	University of Murcia	Spain	19

Table 3. The 10 most cited authors

Authors	Institution	Country	No of Citations
Bishara, Samir E.	University of Iowa	USA	1702
Laffoon, John F.	University of Iowa	USA	1050
Eliades, Theodore	University of Zurich	Switzerland	948
Warren, John J.	University of Iowa	USA	740
von Wald, Lisa	University of Minnesota Twin Cities	USA	666
Millett, Declan T.	University College Cork	Ireland	580
Scribante, Andrea	University of Pavia	Italy	539
Ajlouni, Raed	Texas A&M University College Station	USA	532
Jacobsen, Jane R.	University of Iowa	USA	522
Oonsombat, C	University of Iowa	USA	351

The average number of citations was calculated by dividing the total number of citations of a certain group of studies received by the number of studies. This parameter was also used when evaluating effective authors, studies, institutions, countries, and journals. Average normalized citation counts were used as a color scale in the Vosviewer visualizations. The average normalized number of citations were found by dividing the number of citations of the relevant study by the average number of citations of all studies published in the same year. It is a parameter that can be used to balance the effect of the year of publication on the number of citations.

Normalization procedures were implemented to ensure the accurate analysis of author and institution contributions. To prevent confusion between different authors with the same surname, full name and surname combinations were used, and authors were evaluated alongside their institutional affiliations. Unique author identifiers (Author ID) from the Web of Science database were employed to accurately track contributions from authors with the same name. Institutional names were standardized across the dataset to ensure consistency, combining different variations under a single unified name.

3. Results

The study was conducted with studies obtained from the WoS database. 1497 relevant studies published between 1981 and 2023 were evaluated. The total number of citations is 22413, average number of citations is 14.97 and the h-index is 56.

Fig. 1 shows total number of publications and the total number of citations over the years. In 1981 there was one publication. The analysis revealed a consistent upward trend in the number of publications over the years since 1988, with articles published between 2002 and 2009 being the most cited. Table 1 shows the information of the 20 most cited studies.

In terms of authorship, the analysis identified 4,161 authors who have contributed to the orthodontic bonding literature. The average number of citations per author is 5.38. Samir E. Bishara emerged as the most prolific, not only leading in the number of publications (Table 2) but also in total citations (Table 3), with 51 publication and 1702 citations and underscored his pivotal role in advancing the field. Other prominent authors was Theodore Eliades, Tancan Uysal, and John F. Laffoon. Regarding the collaborations between authors, it was observed that there were local collaborations (Suppl. Fig. 1).

In total, 1,170 institutions and 85 countries produced studies on the subject. The University of Iowa was the most productive and most cited institution, with 55 publications on this topic and a total of 1852 citations. This was followed by King Saud University with 37 publications and Selçuk University with 35 publications. (Table 4). Regarding the collaborations between institutions, it was observed that there were local collaborations (Suppl. Fig. 2). The USA was the country that published the most articles with 231

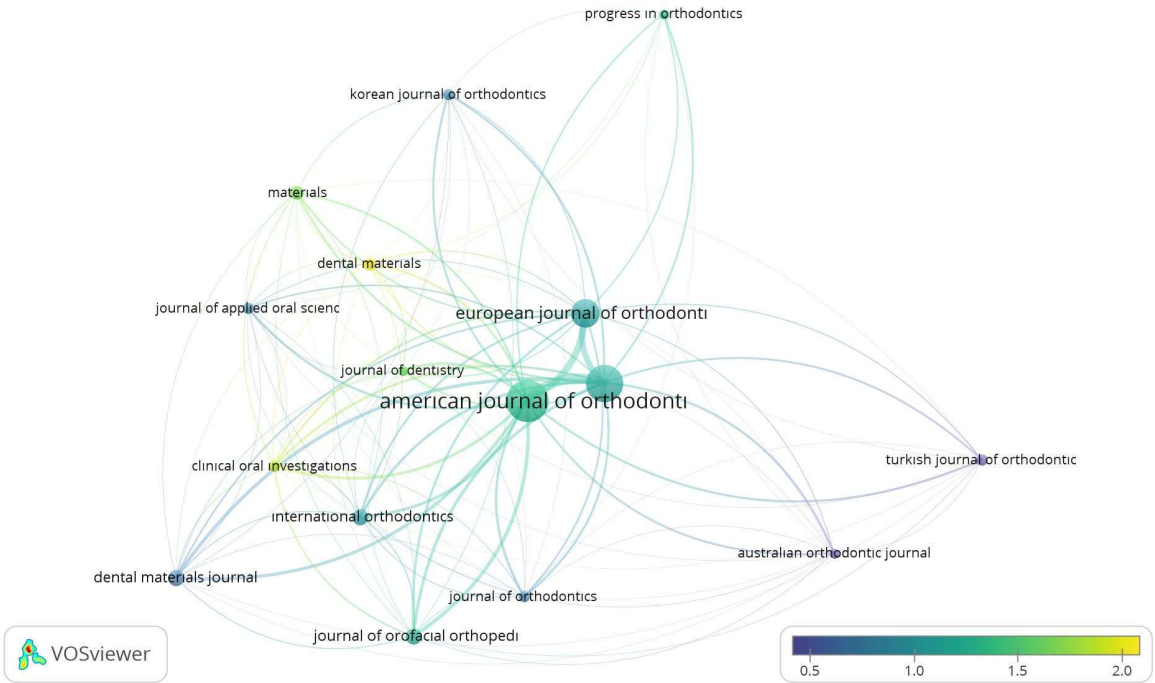

Fig 2. Mapping of the journal analysis with VosViewer. The circles represent the journals. The size of the circles represents the number of publications in the journal. Journals with 15 or more publications were analyzed and visualized. The color of the circles is represented on the scale below. Yellow circles represent a high average normalized citation count.

Table 4. The 10 most productive institution

Institution	Country	Number of Articles	Number of Citations	Citations per Article	H-Index
University of Iowa	USA	55	1852	33.67	27
King Saud University	Saudi Arabia	37	367	9.92	12
Selçuk University	Turkey	35	682	19.49	15
University of Zurich	Switzerland	35	616	17.6	15
Erciyes University	Turkey	31	375	12.1	14
Tahran University of Medical Science	Iran	29	359	12.38	10
University of Pavia	Italy	29	570	19.66	13
University of London	England	28	568	20.29	14
Nihon University	Japan	27	373	13.81	11
On Dokuz Mayıs University	Turkey	26	457	16.98	14

articles, which constitutes 15.43% of the total number of articles published. Turkey (216 publications) and Brazil (121 publication) were the most productive countries after the USA. Approximately 1/3 of the studies were conducted in these countries. The USA also ranked first in terms of the total number of citations with 5,582 citations. Turkey and the England followed the USA with 3,061 and 1,742 citations, respectively. (Table 5). England and Italy showed most high citation rate per article after USA, with 24.16, 21.24 and 16.11 respectively (Table 5). USA, Saudi Arabia and England were active countries in terms of collaboration (Suppl. Fig. 3).

234 journals had articles on the subject. American Journal of Orthodontics and Dentofacial Orthopedics (258 publications) had the highest number of publications and citations. This was followed by Angle Orthodontics (203 publications) and European Journal of Orthodontics (118 publications). Dental Materials and Clinical Oral Investigations were the journals with the highest average number of normalized citations (Fig. 2).

The co-occurance map (Fig. 3) shows the most frequently used key terms and concepts in the studies. Shear bond strength (341), orthodontic brackets (274), orthodontic (126), bond strength (105), and adhesive (103) were used more than 100 times.

4. Discussion

The stability of the orthodontic attachments on the teeth carries the force produced by the archwire to the teeth. Bonding success plays an important role in the effectiveness and success of orthodontic treatment.[15] Table 1 shows the 20 most cited articles in orthodontic bonding. In the top 20 most cited studies, there are 19 original articles and 1 review. It is inevitable that older studies receive more citations regardless of their impact. The true impact of an article can only really be determined after at least 20 years from the date of publication.[16] In this analysis studies with high average normalized citation counts were presented in Supp. Fig. 4.

A bibliometric study conducted to evaluate the trend in orthodontic publications [17] and bibliometric studies evaluating the 100 most cited articles published in the field of orthodontics [18,19], found that the most productive country is the USA, as in this study. And also the leading name in the orthodontic bonding field with the highest number of publications and citations is Samir E. Bishara, University of Iowa (USA).

In the present study, most of the studies in dataset are original articles. There are 49 reviews, 22 proceeding papers, and 2 book chapters. Most of the studies were planned in vitro. In contrast to our study, bibliometric analyses in the field of orthodontics showed a high proportion of clinical [18], cross-sectional [17,19], longitudinal [19],and prospective studies [20].

In the study of the 100 most cited systematic review and meta-analysis in orthodontics [21], there is one study [22] on orthodontic bonding and this is a meta-analysis of in vitro studies. In theory, clinical studies are hypothetically the best way to determine the properties of bonding systems. However, it does not seem possible to clinically determine the adhesion capacity and other properties of bonding systems independently from other variables that can influence the quality and the longevity of bracket bonding to enamel.[23] In vitro studies appear to enable the creation of more standardized study protocols.[22]

In the twenty most cited articles, one of the most popular topics is the use of self-etch primers. In the use of self-etch primers, the bond strength and the area of adhesion failure (ARI Score) were evaluated.[24–28] The bonding efficiency of hydrophilic primer, conventional primer, and self-etch primer against contamination was investigated.[29,30] There are also studies evaluating the effects of self-etch on enamel compared to conventional etch. Enamel loss [31], depth of penetration in the enamel [32], and surface roughness (with SEM) [26,27] are the issues evaluated. One of the most important problems encountered during orthodontic treatment is enamel demineralization. The modified composite with antimicrobial nanoparticles on adhesion and antimicrobial properties are among the topics of interest.[33]

When we look at co-occurrence analysis, the most frequently mentioned key terms and concepts were shear bond strength, orthodontic brackets, orthodontic, bond strength and adhesive. Evaluating the bond strength of brackets has been an important objective. The most appropriate parameter to evaluate this in an in vitro study is shear bond strength measurement. In bibliometric studies on dental adhesives, bond strength[34,35] and shear bond strength [35] were found to be frequently used key terms and concepts. In recent years, frequently used key terms and concepts are demineralization, antibacterial, white lesion, nanoparticle, surface roughness and laser. It has been seen that the preservation of tooth structure has gained importance. It is desired to prevent irreversible changes in the enamel during and after orthodontic treatment. More clinical studies can be done on modified adhesives containing antibacterial nanoparticles and fluoride-releasing adhesives. Widespread clinical use may offer an alternative that can preserve tooth structure regardless of patient cooperation.

Nowadays, orthodontic treatments with clear aligners are becoming more common. There is one study in this data set on

Table 5. The 10 most productive country.

Country	Number of Articles	Proportion of Articles	Number of Citations	Citations per Article	H-Index
USA	231	%15.43	5582	24.16	41
Turkey	216	%13.36	3061	15.24	29
Brazil	121	%8.08	1289	10.65	19
Iran	97	%6.48	887	9.14	15
Japan	85	%5.67	1139	13.4	20
England	82	%5.47	1742	21.24	25
Saudi Arabia	79	%5.27	606	7.67	14
Germany	78	%5.21	1082	13.87	20
India	74	%4.94	600	8.11	14
Italy	63	%4.20	1015	16.11	19

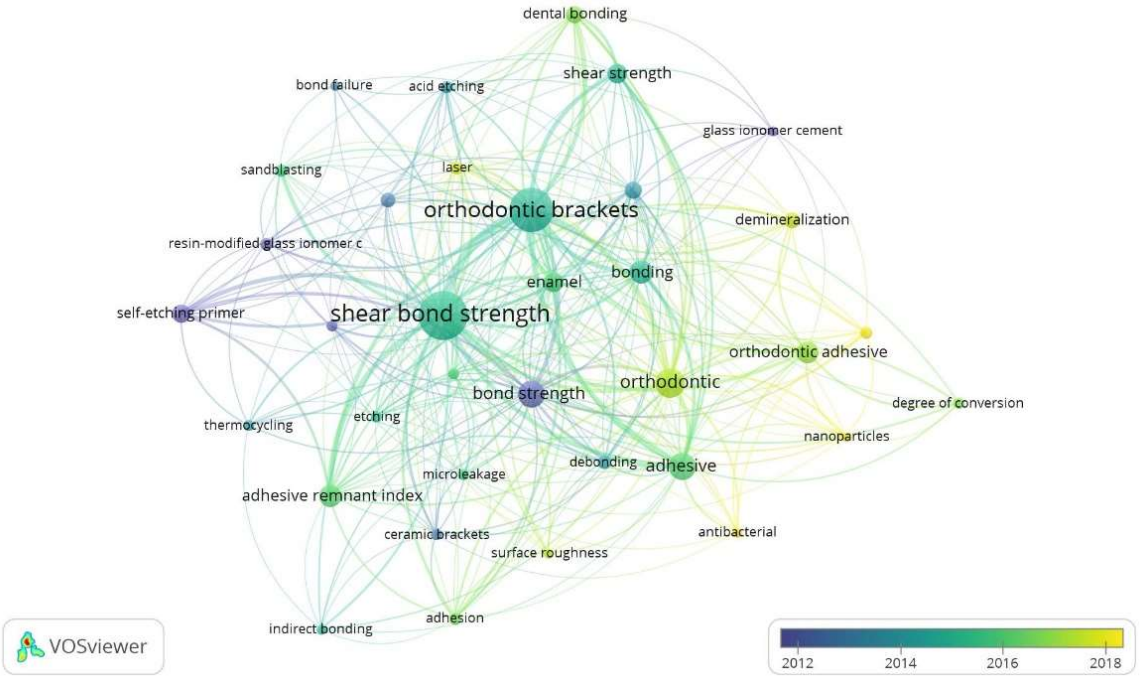

Fig 3. Mapping of the Co-occurance analysis with VosViewer. The circles represent the words and concepts used. The size of the circles is the frequency of use. Words and concepts used 15 times or more were analyzed and visualized. The color of the circles indicates years as indicated in the scale below.

the bonding of composite attachments used during aligner treatments.[36] In the bibliometric analysis of the 50 most cited studies on clear aligners, there is no study on the bonding of composite aligner attachments.[37] The number of studies evaluating the bonding of attachments used in clear aligner treatment should be increased.

There are three journals with over 100 publications in this field. (American Journal of Orthodontics and Dentofacial Orthopedics, Angle Orthodontics, European Journal of Orthodontics). These are the most established and prestigious journals in the field of orthodontics. In a bibliometric study conducted to evaluate the trend in orthodontic publications, these three journals were the main journals with regard the production volume.[17] Among the top ten journals, there are three journals related to dental materials. Dental Materials is a journal with a high normalized citation count in this field. With the development of adhesives and adhesive techniques, studies is shifting towards the materials used.

The limitations of this study were as follows: The WoS database was used as the data source in this study. WoS widely utilized source database for bibliometric and citation analysis across all academic disciplines.[38] Scopus does not record citations published before 1995. Google Scholar also includes citations from non-scholarly publications.[39] These two situations are likely to produce inappropriate results. The most important reason why the WoS database was chosen in our study is that it measures citations in scientific articles from 1945 to the present.[40] But some studies may not be available in all databases. Studies not included in WOS could not be included in the dataset of this study. Secondly, studies in English were included in the data set. Studies in other languages were neglected. And thirdly, citation analysis finds influential studies. However, the reason for the citation is not clear. The citation may have been made to support the related studies, or it have may been made to refute it. It does not reveal high quality but under-cited studies. New studies appear less influential than older studies.

5. Conclusion

This bibliometric analysis offers a detailed examination of the orthodontic bonding literature, illuminating the field's growth, key contributors, and emerging research trends. The study found that the USA, Turkey, and Brazil are the leading countries in research output, with significant contributions from authors like Samir E. Bishara and institutions such as the University of Iowa. The focus on topics like shear bond strength, self-etch primers, and antimicrobial adhesives indicates a shift towards developing materials that improve bonding efficiency while minimizing harm to tooth enamel. These insights provide a clearer understanding of the current research landscape and highlight the areas where further innovation is needed.

However, this study has its limitations, primarily the reliance on the WoS database and the exclusion of non-English publications, which may have led to the omission of relevant research from other databases or languages. Future studies could address these limitations by incorporating additional data sources and expanding the linguistic scope. Despite these constraints, this analysis lays a solid foundation for future research in orthodontic bonding, guiding researchers, clinicians, and industry professionals toward new opportunities for innovation and improvement in adhesive technologies.

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The authors declare that no conflict of interest is available

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Review Article

Cardiovascular Diseases and Apical Periodontitis, Connection of Two Pathologies in Adult Patients; A Systematic Review

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CLINICAL SIGNIFICANCE

Any source of infection, even without clinical signs that force the patient to come to dentist urgently, serves as source of temporary bacteremia in blood, which with specific attacks with different durations, targets tissues of inner walls of blood vessels.

ABSTRACT

Objectives: The objective of this research was to examine the potential relationship between apical periodontitis and arteriosclerosis.

Materials and Methods: A specific query was applied to the Pubmed page containing medical articles. Three independent reviewers were tasked with the collection and selection of articles for inclusion in the study. The selected data items consisted of the year of publication of the article, the article's purpose, the specific name of the bacterium, the causes of endodontic pathology, and the definitive or evasive conclusion of the published article.

Results: The present study included a total of 25 articles. Four review-type studies were identified that demonstrated a positive correlation between apical periodontitis and cardiac diseases. Articles primarily focused on the association between apical periodontitis and cardiovascular diseases, without specifying a specific bacterial strain. The available data suggests that the combination of cardiac examinations and blood tests is the most prevalent methodology employed. A strong or relative interconnection was observed between the pathologies of apical periodontitis and cardiac diseases.

Conclusion: Research indicates that there is a notable correlation between apical periodontitis and cardiac pathologies. It is worth noting that the inflammatory markers found in blood are not specific enough to enable the accurate diagnosis of apical periodontitis.

1. Introduction

Endodontic pathogens are part of the bacterial plaque, but with the characteristic that when these pathogens are given the opportunity to enter the sterile tissue of the pulp tissue limited to the solid walls of the pulp chamber and the tooth root canals, these pathogens, such as Porphyromonas Gingivalis, Prevotela Intermedia or Actinomyces, turn into dangerous pathogens for periapical tissues as well. Precisely in the periapical tissue areas, these pathogens come into contact with the immune cells of the affected individual.[1,2,3] The battle between endodontic pathogenic bacteria and the host's immune cells can have effects beyond the affected area. For instance, it can cause arteriosclerosis in distant parts of the body, such as the heart or brain.[2,3-5]

Several articles have focused on assessing the risk of patients with apical periodontitis for developing arteriosclerosis, and vice versa. These studies have often concluded that the elimination of apical periodontitis through endodontic protocols, with or without systemic administration of antibiotics, is effective in reducing the risk of arteriosclerosis.[6-7] The main underlying cause of the possible connection between these two pathologies is attributed to the endodontic bacterial flora.[7,8] The bacterial organization within the pulp chamber or root canals, taking the form of a biofilm, acts as a protective and enhancing agent, thereby increasing bacterial resistance and pathogenicity.[3,6,9-11]

If the presence of certain actors is confined to the canals of the tooth roots, their impact is limited to the pulp without extending beyond it. Consequently, their effect remains localized and fails to manifest in hard dental structures such as dentin or cementum.[11-13] However, when these actors surpass the tooth's apex into the periapical area, the initial interaction with the host's immune cells is pivotal in establishing a link between the pathology of apical periodontitis and other organs of the host's body.[3,14-16] This connection poses a significant threat to the affected individual's overall health.[2,6,9,12-14]

It has been observed that treated infection foci that require endodontic re-treatment can serve as foci of focal infection, leading to the aggravation of existing cardiac pathologies.[17,18] Several conducted studies have been published that emphasize the potential relationship between the existence of oral diseases and cardiac diseases.[1,2,3] However, there is a question about the availability of sufficient data in the published literature regarding this correlation of pathologies.[19-21] In light of this, it is important to conduct further research to better understand the link between endodontic periapical pathologies and cardiac pathologies, and to develop effective treatment strategies for preventing the progression of these conditions and improving patient outcomes.[2,22-24] In this article, the orientation towards the relationship between apical periodontitis and cardiovascular diseases was to exclude pathological cases involving two systemic pathologies simultaneously, cardiovascular disease and diabetes.[24-28] The purpose of this article is to highlight the close connection between endodontic periapical pathologies and cardiac pathologies.

2. Materials and Methods

2.1. Guidance and eligibility criteria

The systematic review in question used the Prisma transparent reporting guidelines, which are designed to ensure a rigorous and transparent approach to conducting systematic reviews and meta-analyses. The review focused on articles that discuss the pathology of apical periodontitis and cardiovascular diseases in adult patients. In order to ensure the highest level of relevance and

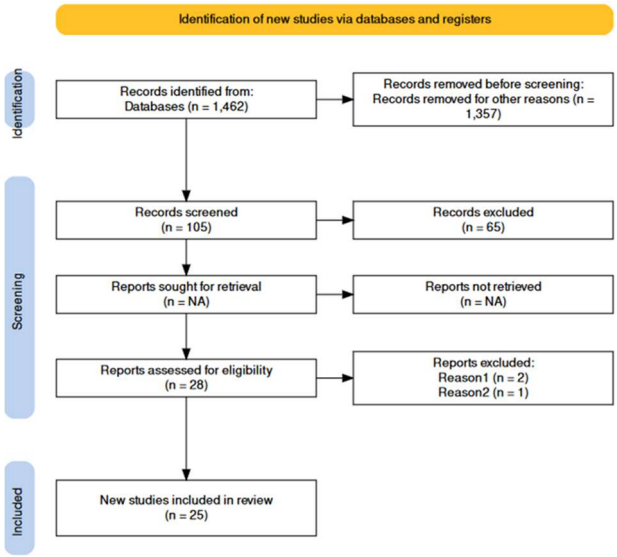

Fig. 1. Flow diagram of the study protocol

accuracy, articles that included patients with diabetes mellitus in addition to the aforementioned pathologies were excluded from the review.

2.2. Information sources and search strategy

The screening process was completed in January 2024. Keywords were applied to the Pubmed page of medical articles with the primary aim of finding initial articles including apical periodontitis and cardiovascular disease. The following query was used to screen the literature via Pubmed Advanced Search: (cardiovascular disease OR artherosclerosis OR Penicillin OR Amoxicillin) AND (apical periodontitis OR endodontic treatment OR endodontics).

2.3. Selection and data collection process

In the collection and selection of articles to be included in the study, three reviewers (I.R, N.A, K.C). worked independently, who were previously familiar with the combination of key words and the manner of their application. The data collected in this way from three reviewers (I.R, N.A, K.C) were further analyzed together, to determine the final number of articles included in the review of this article.

2.4. Data items

The selected data items were: the year of publication of the article, the purpose of the article, the specific name of the bacterium, the causes of endodontic pathology, the concise and definitive or evasive result of the published article.

Table 2. Data on the relationship between cardiac diseases and oral health based on the review type studies included in this study.

The connection between pathologies	Endodontic	Endodontic periodontal	Total
Connection is available	Jakovljevic et al. 2020[3] Noites et al. 2022[1]	Folwaczny et al. 2019[12] Hassan et al. 2021[22]	4 studies
No connection	-	-	-
Total	2 studies – 8%	2 studies – 8%	4 – 16%

3. Results

3.1. Study selection

Upon conducting an analytical examination of the situation from a dental pathology perspective, it was observed that there existed approximately 1,462 articles. However, when a specific query was employed, the aforementioned number was reduced to a mere 105 articles. The second combination of key words had to do with the age of the patients, and with the non-inclusion of diabetes as an accompanying pathology of cardiac diseases in most cases. These found articles were also filtered for 10 years and reached the value of 28 articles for further analysis in this study.

From 28 studies selected for the realization of the purpose of our study, about 25 studies were taken for further analysis based on the inclusion and exclusion criteria during the selection of the study sample. Three of the studies selected in the first phase (3 articles) were excluded because the purpose of these studies did not match the purpose of our study.

A total of 28 articles were selected, of which 3 articles were not taken for further evaluation as they did not meet 1 or some of the following criteria:

1.The article describes the connection between the pathology of apical periodontitis and cardiovascular pathology, but in a patient who also suffers from another pathology before (2 articles).[25,27]

2.The article describes the connection between the pathology of apical periodontitis and cardiovascular pathology, but in a patient who also suffers from another pathology before (1 article).[28]

At this stage, 25 articles were selected as part of the basic articles included in the study (Fig. 1). [1-24,26]

3.2. Findings of the publications

This analysis comprises four review-type studies that investigate the correlation between apical periodontitis and cardiac diseases.[1,2,12,23] Two studies[1,3] reveal a positive correlation between apical periodontitis and cardiac diseases, while the other two studies[12,23] indicate the presence of a connection between cardiac diseases and endodontic/periodontal pathologies (Table 1). The results of review-type studies have demonstrated a correlation between cardiac pathologies associated with endodontic and endodontic/periodontal conditions (Table 2). Table 3 highlights the research trend in this area with a focus on identifying specific bacterial strains. Prior to the COVID-19 pandemic, research mostly centered on the link between apical periodontitis and

Table 1. Review-type studies are presented in this table based on the purpose of the study and the main conclusions reached. The order of placement of the articles respects the ascending order of the year of publication.

Studies	Aim	Conclusions	Oral diseases
Folwaczny et al. 2019[12]	Presentation of the latest data on the oral health of patients with congenital heart disease.	Oral diseases serve as a cause of bacteremia that can cause infective endocarditis in patients with congenital heart disease, but the reverse of this phenomenon is also true.	Endodontic - periodontal
Jakovljevic et al. 2020[3]	Finding the correlation between cardiovascular diseases and apical periodontitis.	There is a weak correlation between the two pathologies. Longitudinal cohort studies are needed.	Endodontic
Hassan et al. 2021[22]	To show how oral diseases can be related to cardiovascular ones.	Endodontic - periodontal	Endodontic - periodontal
Noites et al. 2022[1]	There is insufficient data on the link between oral health and cardiovascular disease.	Weak association between apical periodontitis and cardiac diseases, cohort-longitudinal studies are needed.	Endodontic

Table 3. Studies conducted in vivo with the aim of finding the correlation between oral pathologies and cardiovascular diseases, also classified depending on the year of publication of the article.

The Pathogen	2013-2019	2020-2022
Specific pathogen	Reis et al. 2016[23]	Jimenez et al. 2022[2] Montano et al. 2021[24]
Nonspecific pathogen	Glodny et al. 2013[17] Inchingolo et al. 2013[20] Willershansen et al. 2014[16] Petersen et al. 2014[13] Cotti et al. 2015[19] Vidal et al. 2016[10] Gomes et al. 2016[5] Virtanen et al. 2017[8] Rashmi et al. 2017[15] Allareddy et al. 2017[26] Chauhan et al. 2019[4] Garrido et al. 2019[6] Bergandi et al. 2019[7]	Bilgin Cetin et al. 2020[9] Leao et al. 2022[1]
Total of articles	14 articles – 78%	4 articles – 22%

cardiovascular diseases without identifying a particular bacterial strain.[4-8,10,13,15-17,20] However, in the three-year period following the pandemic, the number of articles that identified specific bacterial flora[2,24] in association with the connection between apical periodontitis and cardiovascular diseases was roughly equal to that of those that did not specify the bacterial strain responsible,[1,9] with a ratio of 1:1.

The correlation between apical periodontitis and cardiac pathologies seen not in the presence of a specific causative pathogen is the subject of Table 4, which outlines the relevant literature. Notably, numerous articles [4,7,9,11-13,17,19,26] examined the relationship between these conditions through cardiac analyses and examinations. In contrast, other publications suggest that blood tests and the monitoring of specific inflammation markers in the blood are essential to control the association between the two pathologies.[6,7,10,15,19,20] A few articles evaluated this relationship by analyzing the change in periodontal index values.[5,8,9,11,13,15-17] However, the data indicate that the combination of cardiac examinations and blood tests[7,19] or blood tests and periodontal indices[15,16] is the predominant methodology. A recent trend in scientific research is the combination of cardiac and periodontal examinations.[9,11] Notably, dental professionals emphasize the importance of combining endo-periodontal indicators with blood tests or cardiac examination techniques in about six articles [9,11, 13,15-17].

Based on the data presented in Table 5, it is evident that an interconnection exists between the pathologies of apical periodontitis and cardiac diseases. Two articles[6,10] strongly support this connection, as evaluated by changes in blood markers. However, the analyses of cardiac parameters do not exhibit a similar strong connection.[4,26] Of particular interest is the strong correlation between cardiac tests and oral pathologies expressed in articles[9,13,14], while for the combination of blood tests and periodontal index, positive[15] as well as negative[16] results have been reported for the association between the two pathologies.

Upon examining the data presented in Table 6 with a focus on specific bacteria, it is notable that there exist three articles containing specific names.[2,23,24] However, only one of these articles[2] discusses the link between apical periodontitis and cardiac diseases with endo-periodontal pathogens. The data presented in Table 7 are expressed based on the references of these articles, specifically for pathogenic flora.

4. Discussion

Based on an analysis of various review type studies that examined the relationship between oral diseases and cardiac diseases, it is evident that a weak correlation exists between the two pathologies. Specifically, data from both longitudinal and retrospective cohort studies indicate that only about 16% of the studies support the existence of this correlation.[3,7,12,26] The data under consideration pertains to the years between 2019 and 2022, which are the corresponding years of the articles included in our study. Specifically, the articles are divided equally, with 50% supporting the notion that endodontic pathology is the root cause of both apical periodontitis and caries, while the other 50% attribute temporary bacteremia in the blood to a combination of periodontitis, apical periodontitis, and caries, which can lead to infective endocarditis.[5,8,12]

Dental caries, a common dental disease, can lead to pulpal pathologies that may result in apical periodontitis. However, when viewed as a pathology that involves bacterial flora, it is comparable to other periodontitis. Therefore, it may be necessary to shift the focus of review studies of this nature towards the pathogens that cause apical periodontitis rather than solely on the name of the pathology, which is distinct from periodontal pathologies.[21,23]

Table 4. Studies about the relationship between oral health and cardiac pathologies seen not in the presence of a specific causative pathogen.

No.	Average age	Heart	Blood	Oral Indexes	Interconnection
2013-2019					
1.	AP[4] 20-40 years	Carotid intima-media thickness	-	-	+
2.	AP[5] 55 years	-	-	Endo-perio	+
3.	AAP[6] 18-40 years	-	Protein C-reactive IL-6, IL-10 MMP-8 E-selectin	-	+
4.	CAP[7] -	Endothelial dysfunction	Il-6, Il-1 TMF-alfa ICAM-1 E-selectin	-	+
5.	AP[8] -	-	-	Endo-perio	+
6.	CAP[10] – 53 years		CPR Il-6 Fibrinogen		+
7.	CAP[13] – 50 years	Abdominal aorta tomography	-	Endo	+
8.	CAP[15] -	-	CRP IL-6 Fibrinogen	Endo-perio	+
9.	CAP[16] -	-	CRP	Endo	-
10.	CAP[17] – 54 years	Tomography arteriosclerotic aorta	-	Endo	+
11.	AP[19] – 31 years	Endotelial Flow	IL-2 TNF – alfa Oksidant status	-	+/-
12.	CAP[20] -		Stresi oksidativ		+
13.	AP[26] 19-65 years	Open cardiac procedures	-	-	+
2020-2022					
1.	AP[9] -	Coronarography	-	Perio	+
2.	AP[11] – 62 years	Angiography	-	Endo-perio	+/-
Total	15 studies	8 studies – 44%	8 studies – 44%	8 studies – 44%	12/2/1 studies

Table 5. Method of evaluation of patients included in studies with the aim of analyzing the relationship between cardiac pathologies and oral health.

The evaluation element	Reference articles	Interconnection	Total
Only the heart	Chaudan N et al.2019 [4]	Impairment in carotid intima media thickness in AP indicates possible correlation!	Evasive +
	Allareddy V et al.2017[26]	Infectious complications in patients with apical abscess are more numerous in cases of open cardiac surgery.	Evasive +
			2 – 11%
Only the blood	Garrido M et al.2019 [6]	Mechanistic connection Modest participation in the impact of endodontic lesions	Evasive +
	Vidal F et al.2016 [10]	Correct endodontic treatment regulates the balance of oxidative stress	Positive
	Inchingolo F et al.2013[20]		Positive
			3 – 17%
Oral only	Gomes MS et al.2016[5]	Age equal to or over 60 years old with hypertension and endodontic pathology has a high risk for cardiac incidents. Regression analyzes indicated a correlation of about 3.83 between AP and cardiac diseases.	Positive
	Virtanen E et al.2017[8]		Positive
			2 – 11%
Heart+blood	Bergandi L et al.2019[7]	The increase in markers in the blood as a result of AP has a potential impact on endothelial dysfunction. CAP may cause a greater effect in men than in women for endothelial dysfunction, as a consequence of the action of estrogen.	Evasive +
	Cotti E et al.2015[19]		Positive
			2 – 11%
Heart+oral	Petersen J et al.2014[13]	CAP without endodontic treatment has more effect than apical radiolucencies with endodontic treatment. CAP is directly proportional while retreatments are inversely proportional to the association between CAP and cardiac disease. Edentulism as a result of periodontitis is also related to cardiac diseases. Univariable studies show that AP is correlated with cardiac disease, while multivariable studies show that AP is independent of cardiac disease.	Positive
	Glodny et al.2013[17]		Positive
	Bilgin Cetin M et al.2020[9]		Positive
	Leao TSS et al.2020 [11]		Evazive +
			4 – 22%
Blood+oral	Rashmi N et al 2017[15]	Systemic levels of Il-6 and fibrinogen are affected by CAP. CRp values have no significant correlation with the number of apical lesions.	Positive
	Willershausen I et al.2014[16]		Negative
			2 – 11%
Total	9 studies positive/ 5 studies evasive +/1 study negative		15 studies

Upon evaluating the in vivo studies conducted, it can be determined that the quantity of articles published between 2020-2022 pertaining to the relationship between oral pathologies and cardiac diseases has decreased by 22%. Furthermore, it is noteworthy to mention that only 17% of the articles in this area of study specify the pathogenic bacteria responsible for the connection, while the remaining 83% examine the relationship between oral pathologies and cardiac diseases through inflammation markers in the bloodstream.[2,7,11] It is observed that roughly 44% of the studies analyze the heart, blood, or oral endodontic and periodontal status as an element of analysis, with almost equal distribution.[6,17]

The evaluation of cardiac functioning and oral endodontic status has yielded positive results when these elements are combined. However, when the evaluation is performed only through blood tests, the results are not as specific to endodontic pathologies.[29-31] In such cases, markers of inflammation in the blood are not sufficient to diagnose the condition accurately. Therefore, the best approach is to identify a combination of specific markers of inflammation in the blood and the presence of apical periodontitis. However, it should be noted that the specific connections between these elements are relatively few in number and not very specific in terms of the connection mechanism.[13,23]

Apical periodontitis, a common dental condition, is often perceived as an endodontic pathology. However, it should be regarded as a periodontal pathology due to its impact on the healthy tissues of the periapex.[7,32,33] Unlike pulpal endodontic infections that are typically confined to the solid walls of the root of the affected tooth, apical periodontitis is not limited by the size of the apical foramen. This unrestricted "wave of attack" can cause significant damage to the healthy tissues of the periapex. The immunological cells that combat the oral bacterial flora are situated in this area, making it a prime target for the members of the oral flora to enter the bloodstream. The oral flora's infiltration into the bloodstream can lead to further damage in other areas of the body.[5,34,35] Therefore, it is crucial to consider the impact of apical periodontitis beyond its immediate location and understand its potential to cause long-lasting harm.

The process of arteriosclerosis causes visible damage to the affected organ via blood attack and related mechanisms, regardless of the location of the affected blood vessel. The heart is one of the organs that undergoes life-threatening consequences as a result of arteriosclerosis. Whether it originates from oral flora or is initiated by sensitive attacks of temporary oral bacteremia,

Table 6. Specific pathogen causing the relationship between oral pathologies and cardiovascular diseases based on the studies carried out in selected publications in accordance with the purpose of the study.

No.	Type of study	Specific pathogen	The evaluative element
2013-2019			
1.	Reis LC et al.2016[23] Cohort study	Streptococci	Bacterial samples from canals before and after mechanochemical preparation
2020-2022			
2.	Jimenez C et al.2022[2] Cross-secional	Porphyromonas gingivalis Porphyromonas endodontalis	Antibodies in the patient's serum Intracanal bacteremia
3.	Montano TCP et al.2021[24] Retrospective	Streptococcus Viridans	The frequency of cardiac diseases, Frequency of caries, apical periodontitis

Table 7. Results of studies after analyzing the specific pathogen responsible for the relationship between oral health and heart disease.

No.	Methodology	Results	Conclusion
2013-2019			
1. Reis LC et al.2016[23] Cohort study	Blood sample after 5 and after 30 minutes after root canal treatment in 32 patients PCR assay	Streptococci In 18% of cases, bacteremia occurs in patients who are not treated with prophylaxis 5 minutes after endodontic treatment 10% of cases presented with bacteremia in patients treated with prophylactic antibiotics	Bacteremia is not detected after endodontic treatment of infected canals. Regardless of receiving prophylaxis or not, streptococci in the blood appeared without significant difference.
2020-2022			
2. Jimenez C et al.2022[2] Cross-secional	In 80 patients under or equal to 40 years old, bacteremia of tooth root canals was evaluated by PCR and antibodies in blood by ELISA.	Porphyromonas gingivalis 22% intracanal Porphyromonas endodontalis 33% intracanal, associated with high endotoxemia	P.endodontalis is associated with increased cardiovascular risk.
3. Montano TCP et al.2021[24] Retrospective	Cardiac and oral profiles were evaluated in 100 patients, 70% men with an average age of pathology diagnosis of about 45 years.	Streptococcus Viridans - valvular voice problems in almost 52% of cases were associated with 96% presence of caries and 45% of apical periodontitis	S. Viridans is the most common cause of infective endocarditis associated with poor oral status.

the manifestation of arteriosclerosis in the heart is of particular concern.[36-39]

Numerous studies have explored the relationship between apical periodontitis and cardiovascular diseases. However, only a limited number of articles have examined this relationship beyond oral bacteria.[39] In vivo clinical studies demonstrating this association are also scarce. The majority of articles on this subject matter are case reports, with the remaining studies primarily focused on analyzing the link between the two pathologies using "in vitro" experiments on animals.[40-42]

Theoretical evidence suggests a potential relationship between periodontitis and arteriosclerosis, albeit limited to inflammation markers in blood tests, which are not exclusive to the link between these two pathologies.[43-47] Moreover, in some cases, cardiac diagnostic tests are used to carry out analyzes, lacking the capacity for specific investigation of the relationship between particular oral bacterial pathogens and the underlying causes of the aforementioned association.[48]

The aging process, a physiological phenomenon, is often accompanied by the simultaneous occurrence of several systemic diseases.[42] The co-occurrence of diseases such as diabetes and cardiovascular diseases, nephritis and cardiovascular diseases, and pathologies with embolic etiology of the brain and cardiovascular pathologies makes it challenging to analyze the close relationship between periodontitis and cardiovascular diseases.[49,50] There is a dearth of review-type studies in the form of meta-analysis on this topic. Furthermore, studies on the role of antibiotic treatment and the destruction of the oral bacterial flora are scarce, thereby reducing the possibility of negative effects of temporary oral bacteremia on existing systemic pathologies. Patients suffering from apical periodontitis, regardless of the different forms of this pathology, are often left with few options for treatment.[1,3,49,50]

It is important to emphasize that apical periodontitis is a type of endodontic pathology that requires specific treatment approaches. One of the main challenges in treating apical periodontitis is the risk of temporary oral bacteremia that can occur during endodontic re-treatments. This bacteremia refers to the presence of bacteria in the bloodstream that can cause infections in other parts of the body. While temporary oral bacteremia is usually harmless, it can pose a risk for patients who have underlying medical conditions that weaken their immune system. Therefore, it is crucial for dental practitioners to take necessary precautions to minimize the risk of temporary oral bacteremia during endodontic re-treatments. This can include the use of antimicrobial agents and the proper management of the root canal system. By doing so, dental practitioners can help ensure the best possible outcomes for their patients and reduce the risk of complications.

Many articles discussing the topic of the relationship between apical periodontitis and cardiovascular pathologies share a common characteristic: they tend to emphasize the limited number of articles on which their discussion of the results is based,

Many articles discussing the topic of the relationship between apical periodontitis and cardiovascular pathologies share a common characteristic: they tend to emphasize the limited number of articles on which their discussion of the results is based, and the lack of conclusive evidence on the topic. Upon conducting a detailed observation of the articles, it was found that the number of patients included in the studies was relatively small.5,8,12,15-19 Therefore, it is clear that further research, particularly of the longitudinal type, is necessary to gain a better understanding of the relationship between apical periodontitis and cardiovascular pathologies. In other words, to draw more definitive conclusions about the topic, we need to conduct more studies with larger sample sizes and a longer follow-up period.

The topic of endodontic treatments and re-treatments remains a hot topic in the field of dentistry due to the fact that humans live with the oral flora throughout their entire lives. This flora can cause attacks starting from adolescence, and become even more sensitive in the age of geriatrics. As a result, it is important to consider the typology of systemic diseases from which the patient who is undergoing treatment for apical periodontitis is suffering when developing protocols for endodontic treatments and re-treatments. By adapting these protocols to the specific needs of the individual patient, it is possible to ensure that the treatment is effective and safe, regardless of their age or underlying health conditions.

5. Conclusion

The link between endodontic pathologies and cardiac diseases warrants evaluation from the perspective of oral pathogens causing temporary bacteremia in the bloodstream, leading to infective endocarditis and other related conditions. This relationship is better assessed through the types of review studies that focus on oral pathogens rather than the name of the oral pathology. Similarly, the correlation between cardiac pathologies and apical periodontitis is more significant when the patient with cardiac pathologies is examined for the presence or absence of apical periodontitis, as opposed to the reverse. In vivo clinical studies in patients indicate this trend, with fewer studies confirming the opposite correlation. However, inflammatory markers in the blood are insufficient for diagnosing apical periodontitis. Future studies are required to establish the parameters of specific markers of inflammation in the bloodstream and oral endodontic or periodontal indices to draw a more definitive conclusion.

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