

Comparison of root dentin damage induced by three techniques for cast post removal

ABSTRACT

Aim: To investigate root dentin defects induced by different cast post removal techniques.

Methodology: One hundred bovine incisors were standardized to 15 mm. Twenty roots served as unprepared controls; the remaining 80 were instrumented with the BioRace system (to size 40/.04), obturated using lateral condensation, and prepared for post space with #1-4 Largo drills. Of these, 60 received directly fabricated cast posts cemented with zinc phosphate. Post removal was performed using ultrasonic vibration, a carbide bur, or a spring-activated device. Roots were sectioned at 4, 8 and 12 mm from the apex and examined at 25× magnification to assess the presence of fractures and other dentinal defects (partial cracks and craze lines). Data were analyzed with the Chi-square test ($\alpha = 0.05$) and Bonferroni-adjusted pairwise z-tests.

Results: Among 300 sections, 103 (34.3%) showed defects. The control group showed none. All removal techniques produced defects, with no significant difference among protocols for other defects ($P > 0.05$). The spring-activated device was associated with a higher number of root fractures ($P < 0.05$). Defects distribution was similar across root levels (4, 8 and 12 mm).

Conclusions: All techniques caused dentin damage. Only the spring-activated device increased fractures. Careful selection of the removal strategy is advised.

Cleiner Naves Ribeiro Carvalho¹
Júlia Moreira Soares²
Letícia Junqueira de Pádua Sesti Gomes
Moussa³
Gustavo Silva Chaves²
Daniel de Almeida Decurcio^{3,4}
Cynthia Rodrigues de Araújo Estrela³
Carlos Estrela⁴
Orlando Aguirre Guedes³

¹ Department of Oral Sciences, University of Cuiabá, Cuiabá, Brazil

² Department of Endodontics, Pontifical Catholic University of Goiás, Goiânia, Brazil

³ Department of Endodontics, Evangelical University of Goiás, Anápolis, Brazil

⁴ Department of Stomatology, Federal University of Goiás, Goiânia, Brazil

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Corresponding Author*

Orlando Aguirre Guedes | Department of Endodontics, Evangelical University of Goiás, Av. Universitária Km 3,5, Cidade Universitária, Anápolis, 75083-515, Brazil | Tel: +55-62-3310-6600 | e-mail: orlandoaguedes@gmail.com.br

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Introduction

Signs of root canal treatment failure, such as persistent periapical radiolucency or associated clinical symptoms, typically signal the need for additional intervention (1). These indicators are often related to microbial persistence that surpasses host defense mechanisms (2-4). In teeth restored with cast metallic posts, such conditions are not uncommon (2), and necessitate nonsurgical endodontic retreatment (1). A crucial step in such procedures is the unobstructed access to the root canal system, which requires effective and safe post removal (5, 6).

A variety of techniques and devices are available for dislodging intraradicular posts, including spring-activated traction systems, carbide burs, and ultrasonic devices (5, 7, 8). Carbide burs work by abrading the post material (5), whereas ultrasonic devices use high-frequency vibrations to break the bond between post and dentin (9, 10). Spring-activated systems apply axial traction to extract the post mechanically (11). Endodontic and restorative procedures, including root canal preparation, filling, retreatment, and post space preparation, have been shown to cause structural changes in root dentin (12-15). These alterations can serve as precursors to vertical root fractures, threatening the long-term prognosis of treated teeth (16). Nevertheless, there is limited evidence regarding the formation of such defects specifically following post removal (6, 7, 17, 18). To date, the mechanical effects of removing cast metal posts with carbide burs or spring-loaded systems have not been thoroughly investigated.

Therefore, the present study evaluated the occurrence of root dentin defects after cast post removal using ultrasonic vibration, carbide burs and a spring-activated device. The tested null hypotheses were that (i) the type of post removal technique would not influence the occurrence of root fractures or

other dentinal defects, and (ii) these outcomes would not vary across different root levels.

Materials and Methods

Sample size calculation

The sample size was determined based on previously reported effect sizes for dentinal defects caused by post space preparation drills (19) and ultrasonic removal methods (7). Using G* Power software (version 3.1.2; Heinrich Heine, Universität Düsseldorf, Düsseldorf, Germany), with $\alpha = 0.05$ and power $(1-\beta) = 0.80$, the minimum requirement was calculated as 12 samples per group.

Sample selection and preparation

One hundred bovine incisors with complete root formation and similar morphology were selected. Preoperative radiographs (buccolingual and mesiodistal) confirmed comparable root canal widths and straight configurations (6, 19). Teeth presenting anatomical anomalies, excessive curvature, or calcifications were excluded.

Coronal portions were removed using a diamond disc (KG Sorensen, São Paulo, SP, Brazil) perpendicular to the tooth's long axis, yielding a standardized root length at 15 mm. Under 20 \times magnification (Expert DN; Müller Optronic, Erfurt, Germany), roots were inspected for cracks or surface defects. Any root showing preexisting damage was discarded and replaced.

To simulate the periodontal ligament, each root was coated with a silicone impression material (Aquasil; Dentsply Maillefer, Ballaigues, Switzerland) before embedding in acrylic resin blocks (6, 20). Twenty roots were left unprepared as negative controls (Group 1), while the remaining 80 roots underwent canal instrumentation, obturation and post space preparation.

Instrumentation and obturation

Canal patency was confirmed with a #10 K-File (Dentsply Maillefer, Ballaigues, Switzerland). Roots allowing



passage of files larger than ISO #15 K-File (Dentsply Maillefer, Ballaigues, Switzerland) were replaced (21). All roots were instrumented to a working length (WL) of 14 mm (1 mm short of the apex) using a crown-down technique with the BioRace rotary system (FKG Dentaire, La Chaux-de-Fonds, Switzerland) operated by a torque- and speed-controlled motor (X-Smart Plus; Dentsply Maillefer, Ballaigues, Switzerland), using the following sequence: BR0 (#25/.08), BR1 (#15/.05), BR2 (#25/.04), BR3 (#25/.06), BR4 (#35/.04), and BR5 (#40/.04) as the master apical file. Each instrument was used for the preparation of five root canals and was operated at a rotational speed of 600 rpm and 1.5 N/cm torque.

Irrigation was carried out with 3 mL of 2.5% sodium hypochlorite (NaOCl; Pharm, Phloraceae, Cuiabá, MT, Brazil) between each file using a 31-gauge NaviTip needle (Ultradent, South Jordan, UT, USA) positioned 1 mm short of the WL with gentle up-and-down motion, avoiding binding. Final irrigation comprised 3 mL of 17% EDTA (Biodinâmica, Ibiporã, PR, Brazil) for 3 min, followed by 3 mL of 2.5% NaOCl (Pharm, Phloraceae, Cuiabá, MT, Brazil). Irrigating solutions were used at room temperature without activation. All roots were re-examined under 20× magnification (Expert DN; Müller Optronic, Erfurt, Germany), and no defects were detected.

Before obturation, canals were dried with sterile paper points (Dentsply Maillefer). Lateral condensation was used for obturation with a gutta-percha master cone (Dentsply Maillefer, Ballaigues, Switzerland) and Sealapex sealer (SybronEndo, São Paulo, SP, Brazil), which was mixed according to the manufacturer's instructions. Accessory cones were inserted with a size B spreader (Dentsply Maillefer, Ballaigues, Switzerland). The coronal excess was removed with heated instruments and sealed with temporary restorative material (Vidrion R; SS White, Rio de Janeiro, RJ, Brazil). Radiographs

confirmed the obturation quality. Roots were stored at 37°C and 100% humidity for one week to ensure complete setting of the sealer.

Post space preparation and cementation

After removal of the temporary material, a 10-mm post space (measured from the cervical surface) was created, preserving a 4-mm apical seal. Gutta-percha was initially removed with flame-heated vertical condensers. Subsequently, #1-4 Largo drills (Dentsply Maillefer, Ballaigues, Switzerland) were used sequentially to refine the post space. Canals were irrigated with 3 mL of 2.5% NaOCl (Pharm, Phloraceae, Cuiabá, MT, Brazil) after each drill change and dried with sterile paper points (Dentsply Maillefer, Ballaigues, Switzerland).

Twenty roots remained with only post space preparation (Group 2). For the other 60 roots, cast posts were fabricated using a direct technique with acrylic resin (Duralay; Reliance Dental, Worth, IL, USA) and polycarbonate posts (Pinjet; Angelus, Londrina, PR, Brazil). Patterns were standardized to 4 mm coronal height, cast in copper-aluminum alloy (Goldent L.A.; Comercial Importação e Exportação, São Paulo, SP, Brazil), sandblasted with aluminum oxide, and adjusted (6).

Zinc phosphate cement (SS White, Rio de Janeiro, RJ, Brazil) was used for luting, applied with a lentulo-spiral (Dentsply Maillefer, Ballaigues, Switzerland). Finger pressure was maintained for 1 minute. Excess cement was removed, and roots were stored again at 37°C and 100% humidity for one week. These 60 specimens were allocated into three experimental groups (n = 20), by a computer-generated randomization list, each subjected to one of the post removal methods.

Ultrasonic vibration (group 3)

The coronal part of each post was reduced using a #3069 bur (KG Sorensen, São Paulo, SP, Brazil) (6). Ultrasonic

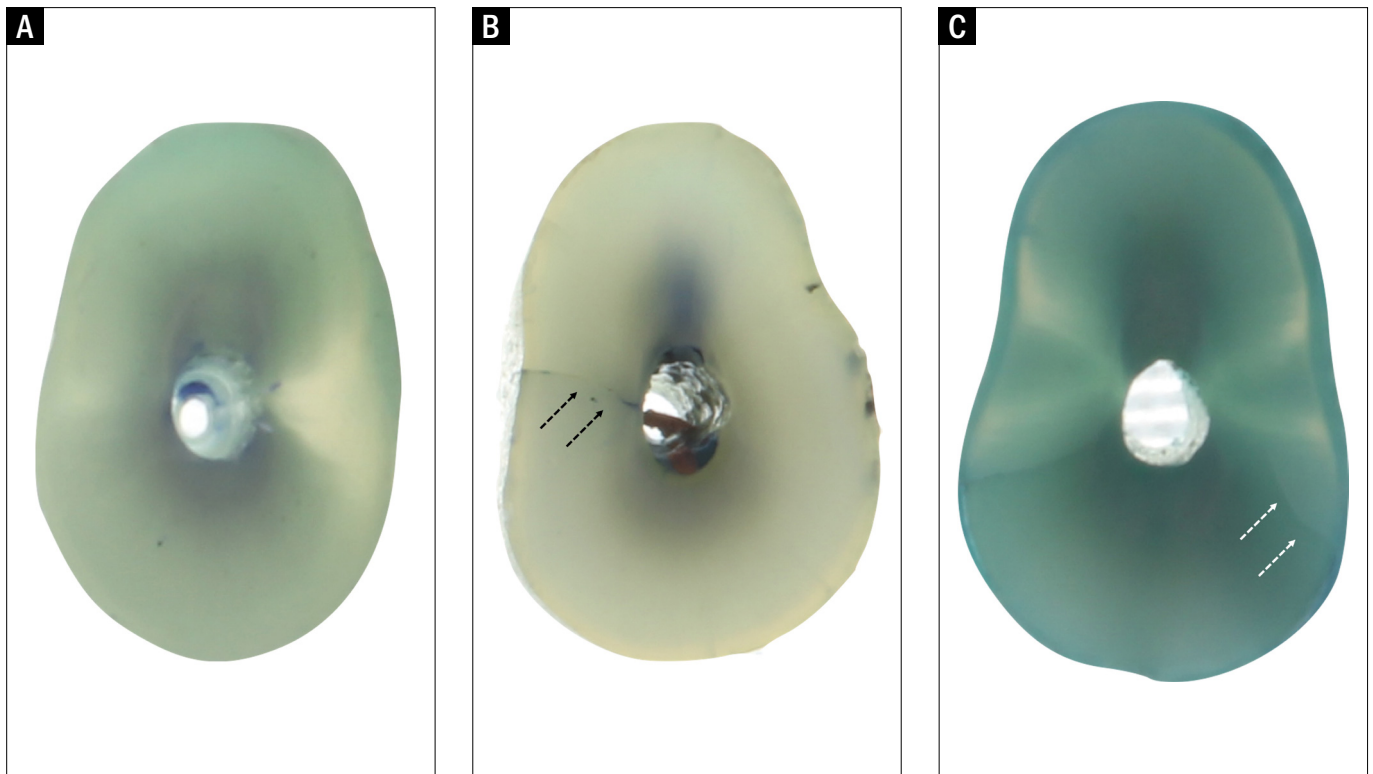


Figure 1
Representative images of root slices **(A)** Root slice without defects. **(B)** Root slice showing a root fracture (black arrows). **(C)** Root slice showing a partial crack (white arrows)

vibration was applied using an EMS PM 200 ultrasonic unit (EMS - Electro Medical Systems S.A., Nyon, Switzerland) and E12 tip (Helse Ultrasonic, Santa Rosa de Viterbo, SP, Brazil). The tip was placed perpendicularly at the cervical margin (10), and activated at 80% power with continuous water cooling for 1 minute on each surface (buccal, lingual, mesial and distal), totaling 4 minutes per tooth (6). Post removal was confirmed visually and radiographically.

Carbide bur (group 4)

Post removal was performed by mechanical wear using a #1/2 carbide bur (Dentsply Maillefer, Ballaigues, Switzerland), ensuring that the bur remained in contact exclusively with the post and avoiding contact with the surrounding tooth structure. Wear progression in the apical direction was monitored radiographically, with images taken at multiple angulations. The post was considered completely removed when no remnants were visible

in the radiographs. The carbide bur was replaced after every five post removal (11).

Spring-activated device (group 5)

Small horizontal grooves, approximately 1 mm deep, were created on the buccal and lingual surfaces of the coronal portion of the post using a #1/2 carbide bur (Dentsply Maillefer, Ballaigues, Switzerland), allowing proper adaptation and fixation of the traction tip. After adjusting the spring pressure to level 1, the traction tip was inserted into the groove, and the spring-activated device (Otto Metalúrgica Arminger, São Paulo, SP, Brazil) was positioned parallel to the long axis of the post. The removal force was applied by pressing the device's trigger, releasing the internal spring mechanism to generate the extraction force (11). The roots were then inspected visually and radiographically to ensure complete post. Throughout the procedures, all samples were kept moist in distilled water to prevent dehydration. One endodontist



and one oral rehabilitator, both with more than 10 years of experience, performed all clinical procedures.

Sectioning and microscopic evaluation

Each root was removed from the resin block, and the silicone layer was detached. Roots were horizontally sectioned at 4, 8 and 12 mm from the apex using a double-faced diamond disc (4" diameter \times 0.012" thickness \times 1/2"; Arbor, Extec, Enfield, CT, USA) mounted on a precision saw (Isomet 1000, Buehler, Lake Bluff, IL, USA), with water cooling. Sections were dried and stained with 1% methylene blue (Pharm, Phloraceae, Cuiabá, MT, Brazil) for defect visualization (21). Slices were examined under 25 \times magnification (Expert DN; Müller Optronic, Erfurt, Germany). Digital images were analyzed and classified into three categories (12). "No defect" was defined as the absence of any lines or cracks on both the internal canal walls and external root surface. "Fracture" was defined as a crack extending from the root canal lumen to the external root surface. "All other defects" included all other visible lines, such as: partial cracks (extending from the root canal wall into the dentine without reaching the external surface) and craze lines (extending from the outer surface into the dentin without contact the canal lumen) (Figure 1 A to C).

A total of 60 images were analyzed in each group. All assessments were performed by a previously calibrated, blinded examiner. Each image was assessed twice, with a one-week interval.

Statistical analysis

The frequency of defects was expressed as counts and percentages for each group. Data were analyzed using IBM SPSS for Windows, version 21.0 (IBM Corp., Armonk, NY, USA). Chi-square test was used to compare groups and assess differences across root levels (4, 8 and 12 mm). Significance was set at

$P < 0.05$. Bonferroni-adjusted z-tests were used for pairwise comparisons. Intraexaminer reliability was calculated using kappa statistics based on 10% of the samples.

Results

The kappa coefficient obtained for intraexaminer agreement was 0.87, indicating excellent reliability in the evaluation of dentin defects.

Among the 300 sections examined, 103 (34.3%) exhibited structural alterations in root dentin (Tables 1 and 2). The vast majority of these defects ($n = 94$; 91.2%) were classified as either partial cracks or craze lines. The control group (Group 1) showed no evidence of defects at any assessed level.

In Group 2, which included specimens subjected to instrumentation, obturation, and post space preparation without post insertion, a small number of fractures were observed (Table 1). When comparing this with the experimental groups (Groups 3 to 5), a statistically significant increase in root fractures was identified only in the group where spring-activated device was employed ($P = 0.007$) (Table 1). Statistically significant differences in fracture incidence were also found among the three cast post removal techniques ($P < 0.05$) (Table 1).

Regarding other types of dentin defects (partial cracks and craze lines), all post removal groups demonstrated a higher number of occurrences compared to group 2, although these differences did not reach statistical significance. Additionally, no significant variation in defect frequency was observed when comparing the three post removal protocols with each other ($P > 0.05$) (Table 2).

With respect to root level distribution (4, 8 and 12 mm from the apex), there were no statistical significance differences in the incidence of root fractures ($P = 0.357$) or other types of defects ($P = 0.323$) (Tables 1 and 2). However, a higher absolute number of defects was



Groups	Root level			Total	P value*
	12 mm	8 mm	4 mm		
G1	0 (0.0%) ^{A,a}	0 (0.0%) ^{A,a}	0 (0.0%) ^{A,a}	0 (0.0%) ^A	>0.05
G2	1 (11.1%) ^{A,a}	0 (0.0%) ^{A,a}	0 (0.0%) ^{A,a}	1 (11.1%) ^A	0.362
G3	2 (22.2%) ^{A,a}	0 (0.0%) ^{A,a}	0 (0.0%) ^{A,a}	2 (22.2%) ^A	0.126
G4	0 (0.0%) ^{A,a}	0 (0.0%) ^{A,a}	0 (0.0%) ^{A,a}	0 (0.0%) ^A	>0.05
G5	1 (11.1%) ^{A,a}	4 (44.4%) ^{A,b}	1 (11.1%) ^{A,a}	6 (66.7%) ^B	0.189
Total	4 (44.4%) ^a	4 (44.4%) ^a	1 (11.1%) ^a	9 (100%)	0.357
P Value*	0.456	0.002	0.401	0.007	

*Chi-square test. G1: Negative control; G2: Instrumentation, obturation and post space preparation; G3: Ultrasonic vibration; G4: Carbide bur; G5: Spring-activated device. Capital letters compare groups in vertical columns and lower-case letters compare groups in horizontal rows.

Groups	Root level			Total	P value*
	12 mm	8 mm	4 mm		
G1	0 (0.0%) ^{A,a}	0 (0.0%) ^{A,a}	0 (0.0%) ^{A,a}	0 (0.0%) ^A	>0.05
G2	7 (7.4%) ^{B,a}	2 (2.1%) ^{A,B,a}	6 (6.4%) ^{A,B,a}	15 (16.0%) ^B	0.155
G3	12 (12.8%) ^{B,a}	12 (12.8%) ^{C,a}	3 (3.2%) ^{A,B,b}	27 (28.7%) ^B	0.004
G4	6 (6.4%) ^{A,B,a}	6 (6.4%) ^{A,B,C,a}	11 (11.7%) ^{B,a}	23 (24.5%) ^B	0.172
G5	12 (12.8%) ^{B,a}	9 (9.6%) ^{B,C,a}	8 (8.5%) ^{B,a}	29 (30.9%) ^B	0.420
Total	37 (39.4%) ^a	29 (30.9%) ^a	28 (29.8%) ^a	94 (100%)	0.323
P Value*	<0.001	<0.001	<0.001	<0.001	

*Chi-square test. G1: Negative control; G2: Instrumentation, obturation and post space preparation; G3: Ultrasonic vibration; G4: Carbide bur; G5: Spring-activated device. Capital letters compare groups in vertical columns and lower-case letters compare groups in horizontal rows.

Table 1

Distribution of root fractures according to post removal technique and root level.

Table 2

Distribution of all other defects according to post removal technique and root level.

recorded in sections obtained at 12 mm and 8 mm (Tables 1 and 2).

Discussion

Endodontic retreatment is usually required because intraradicular infection persists after primary therapy, sustained by biofilms and by limited irrigating solution penetration into complex anatomy (3, 4). In teeth with cast posts, retreatment first demands post removal to re-establish canal access (5, 6). This investigation examined whether different techniques for cast post removal influenced the development of root dentin defects, including root fractures, partial cracks and craze lines. Among the tested protocols - ultrasonic vibration, carbide burs, and a spring-activated device - only the latter

demonstrated a statistically significant increase in root fractures. Based on these findings, the initial null hypothesis was partially rejected.

Several methodologies have been proposed for detecting dentin damage during intracanal procedures, such as thermography (22) and scanning electron microscopy (SEM) (20). However, most insights in this field are derived from studies employing either micro-computed tomography (micro-CT) (23-25) or the root-sectioning method (6, 12-14, 19, 21, 26, 27). Micro-CT offers high-resolution, three-dimensional, non-destructive imaging that allows detailed assessment of structural alterations before and after treatment (23-25). Its primary advantages include the capacity for repeated measures on the same specimen (25) and enhanced



visualization of defect propagation (23-25). Nevertheless, the technique is costly, requires specialized equipment (28), and may be subject to dehydration-related artifacts and limitations in spatial resolution (29).

Conversely, root-sectioning allows for direct visualization of dentin integrity at specific levels, with relatively simple execution and minimal data processing (12, 30, 31). It is particularly useful for studies with large sample sizes and provides a practical means of identifying defect initiation and progression (29). Nevertheless, it is destructive (28), offers only two-dimensional snapshots, and evaluates limited root segments (25), increasing the chance of missing defects (23) or failing to determine their exact moment of formation (23, 24). No universally accepted standard currently exists for the evaluation of dentin defects (19), and further methodological refinement remains necessary. In the present study, all roots were carefully inspected before instrumentation to exclude preexisting damage. While internal cracks not able to be detected on the external surface cannot be completely ruled out, the complete absence of defects in the control group supports the validity of the findings and reinforces that observed alterations were likely induced by the experimental procedures (12, 14, 27). These results are consistent with previous literature that has reported no dentin damage in unprepared or uninstrumented roots (6, 14, 21, 27, 30).

The simulation of periodontal ligament and alveolar socket using silicone material and acrylic resin embedding was adopted to approximate clinical conditions (20, 26, 28, 32, 33). Despite known limitations in mimicking the viscoelastic properties of natural tissues (26, 33), this approach is widely accepted for improving standardization in experimental endodontic research (32). Root specimens were matched for canal diameter at a reference point (9 mm from the apex) to ensure anatomical comparability (32), given the impact of

dentin thickness on mechanical resistance stress (34).

Due to ethical and practical limitations associated with sourcing human teeth (35), bovine incisors were used as a substitute. These teeth exhibit similar physical and mechanical characteristics to human dentin (36), particularly when sourced from older animals, and have been validated in prior studies as reliable alternatives for laboratory experimentation in endodontics (6, 19, 36).

Multiple factors related to the design and properties of the instruments have been implicated in the initiation of microcracks, including cross-sectional geometry, alloy composition, heat treatment, cutting efficiency, instrument size and tip design, pitch and taper variations, flute configuration, the number of instruments used, and the kinematics employed during instrumentation (14, 23, 24, 27, 28). In this study, root canal instrumentation was performed using the BioRace Basic Set, which includes six rotary files: BR0 (#25/.08), BR1 (#15/.05), BR2 (#25/.04), BR3 (#25/.06), BR4 (#35/.04) and BR5 (#40/.04). The BioRace system was chosen due to its design features - alternating cutting edges, non-cutting tip, triangular cross-sectional without radial lands, and electrolytic surface treatment - which have been associated with a lower incidence of dentinal defects (25). Notably, the BR0 and BR3 instruments have high tapers (.08 and .06, respectively), and such taper configuration may increase the contact area with canal walls, thereby concentrating stress and potentially contributing to dentinal defect formation (21, 31). Furthermore, the BioRace system operates under continuous rotation (25), requiring a greater number of rotations to complete instrumentation (15). This increase may generate greater friction between the instrument and dentinal walls, which has also been linked to a higher incidence of dentinal damage (15).

It is well established that the irrigating



solutions used during root canal procedures can influence the structural integrity of root dentin (19). High concentrations of sodium hypochlorite (NaOCl) have been associated with reductions in the elastic modulus and flexural strength of dentin, potentially compromising its mechanical properties (15, 37, 38). To reduce these adverse effects, the present study employed 2.5% NaOCl for irrigation, aiming to preserve dentin integrity during both root canal instrumentation and subsequent post space preparation.

Several root canal filling techniques or their modifications have been proposed to enhance the quality of endodontic sealing (12, 37). Among them, lateral condensation of gutta-percha remains one of the most widely used methods due to its proven clinical efficacy (31), low cost, and the ability to control the apical extent of the filling mass (31). However, despite its widespread use, this technique has been associated with a high incidence of vertical root fractures (39). Shemesh et al. (12) demonstrated that lateral condensation produced a greater number of dentinal defects compared to non-compaction techniques. Similarly, Capar et al. (31) reported a high frequency of root cracks in teeth filled using cold lateral condensation and warm vertical compaction techniques. The design of the digital spreader and the magnitude of the condensation force have been identified as key factors contributing to the formation of root defects during the lateral condensation technique (39).

Post-space preparation has been shown to contribute to both the formation (19) and propagation (18) of dentinal defects. This may be attributed to the rigidity and dimensions of the burs used during preparation (18, 19). Larger and stiffer instruments tend to engage more root dentin surface, thereby increasing friction, stress concentration, and the likelihood of inducing structural defects (19). In the present study, Largo drills were selected due to their widespread use in clinical practice for post-

space preparation (19). Notably, the incidence of dentin defects observed in this study ($n = 16$; 15.53%) was lower than that reported in previous studies, which ranged from 19.95% to 77% (7, 19), but higher than the 6.66% observed by Serpa et al. (6). These discrepancies may be attributed to variations in post space preparation techniques, the type and dimensions of the posts used, and the depth of post placement (7).

The removal of cast metallic posts in endodontically treated teeth with periapical pathologies remains a challenging clinical procedure (6, 7). Over the years, various techniques and instruments have been developed to improve the safety and efficiency of this intervention (5-8). This study evaluated the incidence of dentinal defects associated with three commonly used cast post removal methods: carbide burs, ultrasonic vibration, and a spring-activated device. The selection of these methods was based on prior reports supporting their clinical effectiveness (6-8, 11). Carbide bur removal is widely used due to its accessibility and effectiveness, working through direct abrasion of the metallic post (8, 11). Ultrasonic techniques, in contrast, apply mechanical energy to transmit vibrations to the posts, thereby weakening or disrupting the cement interface between the post and the root dentin (6, 9). Spring-activated systems function by applying controlled mechanical traction forces to dislodge the post (11). All tested cast post removal methods resulted in the formation of dentinal defects (Tables 1 and 2). Among the evaluated techniques, the carbide bur group exhibited the lowest number of defects ($n = 23$; 22.3%). To date, no studies have specifically investigated root dentin damage resulting from the removal of cast posts using carbide burs. However, Campos et al. (8) pointed out a potential drawback of this method, noticing that the abrasion of cast posts composed of copper-aluminum alloy may lead to an increase in temperature, which can be transferred to surrounding

dentinal tissues. This thermal rise may promote dentin dehydration and, consequently, the formation of structural defects. Ultrasonic vibration resulted in an intermediate number of defects ($n = 29$; 28.1%), despite its theoretical advantage of reducing mechanical stress on the tooth structure during post removal. Altshul et al. (7) observed that ultrasonic removal of threaded posts was associated with a high incidence of dentinal defects. Similarly, Satterthwaite and Stokes (17) reported that prolonged ultrasonic application during the removal of zirconium ceramic and stainless-steel posts significantly increased the incidence of root surface cracks. This finding was corroborated by Serpa et al. (6), who observed the occurrence of dentinal defects with the use of one or two ultrasonic units. Dominicini et al. (40) suggested that the vibrational energy generated during ultrasonic vibration application is transmitted from the tip to the post and absorbed by the canal walls, potentially creating localized stress concentrations in the dentin that contribute to defect formation. The use of the spring-activated device resulted in the highest number of dentinal defects ($n = 35$; 33.9%). However, no prior studies have addressed the impact of this technique on root dentin integrity during cast post removal, limiting direct comparison and interpretation of this finding. Further investigations are needed to clarify the biomechanical effects of spring-activated systems on root structure.

A higher number of defects was observed in sections located 12 mm and 8 mm from the apex. The higher incidence of coronally positioned defects may be attributed to the excessive tapering of the root canals, potentially caused by the use of the BR0 (#25/.08) instrument during initial instrumentation (6, 21) and the #4 Largo drill during post space preparation (6, 19). Another possible explanation relates to the application method of the ultrasonic and traction tips. In the present study, both tips were applied adjacent to the cervi-

cal region, close to the cementation line, to maximize the transmission of energy to the cast post (6, 10, 11). This approach may have increased stress concentration in the coronal portion of the root canal walls, thereby favoring defect formation in this region. Further studies are necessary to confirm this finding and better understand the stress distribution associated with each post removal technique. This study has limitations. As an *ex vivo* investigation, the findings may not fully reflect clinical conditions. The results are device- and brand-specific, reflecting only the tips, burs, units, and settings tested, and therefore may not be generalizable to other systems or protocols. Moreover, long-term aging and thermo-mechanical cycling were not simulated, so time-dependent changes in dentin or cements were not assessed.

While the clinical implications of dentin defects remain a subject of ongoing debate, the present findings underscore the need for cautious selection of post removal strategies. Minimizing iatrogenic damage to dentin is essential for preserving the long-term structural integrity and function of endodontically treated teeth. Future research should aim to refine these techniques and develop safer, more predictable approaches for post removal.

Conclusion

All evaluated techniques for cast post removal - using ultrasonic vibration, carbide burs, and a spring-activated device - resulted in the formation of dentinal defects. The spring-activated method was associated with a significantly greater incidence of root fractures when compared to the other removal protocols. Dentinal defects were more frequently observed in coronal (12 mm) and middle (8 mm) thirds of the root.

Clinical relevance

Crack lines and microcracks formed during endodontic and restorative pro-



cedures may progress into vertical root fractures, which are a major cause of tooth loss in root canal-treated teeth. Therefore, identifying the procedures most likely to induce dentin defects is essential for effective prevention.

Author Contributions

C.N.R.C., C.R.A.E., C.E. and O.A.G. designed the study; C.N.R.C., J.M.S., L.J.P.S.G.M., G.S.C. and D.A.D. contributed to data collection and performed statistical analysis; C.N.R.C., C.R.A.E., J.M.S., L.J.P.S.G.M., G.S.C. and D.A.D. drafted the manuscript; C.E., O.A.G. critically revised the article for important intellectual content. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Conflict of interest

All authors declare that they have no conflicts of interest related to this study.

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