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Fracture susceptibility of endodontically treated teeth

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Abstract – *Aim*: To assess the influence of cervical preparation on fracture susceptibility of roots. *Material and methods*: During root canal instrumentation, the cervical portions were prepared with different taper instruments: I: no cervical preparation; II: #30/.08; III: #30/.10; IV: #70/.12. The specimens were sealed with the following filling materials ($n = 8$), A: unfilled; B: Endofill/gutta-percha; C: AH Plus/gutta-percha; D: Epiphany SE/Resilon. For the fracture resistance test, a universal testing machine was used at 1 mm per minute. *Results*: ANOVA demonstrated difference ($P < 0.05$) between taper instruments with a higher value for group I (205.3 ± 77.5 N) followed by II (185.2 ± 70.8 N), III (164.8 ± 48.9 N), and IV (156.7 ± 41.4 N). There was no difference ($P > 0.05$) between filling materials A (189.1 ± 66.3 N), B (186.3 ± 61.0 N), C (159.7 ± 69.9 N), and D (176.9 ± 55.2 N). *Conclusions*: Greater cervical wear using a #70/.12 file increased the root fracture susceptibility, and the tested filling materials were not able to restore resistance.

Root fracture of endodontically treated teeth is a common cause for tooth extraction (1). In this case, the roots fractured could have been caused by weakening of the dentin during the biomechanical preparation and loss of dentin moisture caused by irrigating solutions (2).

Additionally, rotary instruments of different tapers used during the instrumentation may promote tapered root canals. The greater the amount of dentin removed during the preparation, the weaker the dental structure is, thus predisposing the root to fracture (3).

Since the development of materials capable of adhering to dentin, such as resin-based endodontic sealers, it would be advantageous if the radicular canal obturation could decrease the root fracture susceptibility and enhance the clinical longevity of an endodontically treated tooth (4, 5). Epiphany self-etch (SE) is a dual-curing sealer that associates self-etching properties and is employed with the solid material Resilon (Resilon Research LLC, Madison, CT, USA), composed of a thermoplastic synthetic material. The Epiphany/Resilon system is the first obturation system to claim the ability to form a 'monoblock' between the canal walls and obturation material (5, 6). Studies have been performed to evaluate the physical and chemical properties of this new sealer system. Bond strength of this system to root dentin has been similar to other resin-based sealers (7–9). Although some studies have evaluated the fracture resistance of teeth filled using the Resilon/Epiphany system (4, 5, 10, 11), the results in the literature are contradictory in relation to the efficacy in the root reinforcement.

Considering the variety of rotary instruments with different tapers and resin-based sealers, it would be relevant to assess their influence on resistance to fracture of endodontically treated roots. Therefore, the purpose of this *in vitro* study was to evaluate the influence of the cervical preparation with 30/.08, #30/.10 and #70/.12 tapers on the fracture susceptibility of roots filled with different endodontic sealers: Endofill/gutta-percha, AH Plus/gutta-percha and Epiphany SE/Resilon.

Methods

One-hundred twenty-eight human mandibular incisors stored in 0.1% thymol solution at 4°C were selected. All teeth had: (i) a single root at least 12 mm in length and the absence of fractures or fissures, (ii) presence of a single root canal, (iii) absence of calcifications or resorptions checked by a radiological examination and (iv) root thickness 12 mm from the apex between 3.5–3.8 and 2.9–3.1 mm in the buccal and lingual faces, respectively, and 6.3–6.5 mm in buccolingual direction, as checked with a digital pachymeter (Digimess; Shiko Precision Gaging Ltd, Beijing, China). The roots were sectioned transversally at the cementoenamel junction with a carborundum disc (KG Sorensen, Barueri, Brazil) at low speed (Dabi Atlante Ltda, Ribeirão Preto, Brazil) to obtain a length of 12 mm.

The root canals were initially explored by introducing a #15 K file (Dentsply-Maillefer, Ballaigues, Switzerland) until it was seen at the apical foramen. The working length was established by subtracting 1 mm from this measurement.

Roots were randomly assigned into four groups according to the taper instruments used for cervical preparation: Group I: no cervical preparation (control); Group II: #30/.08; Group III: #30/.10; Group IV: #70/.12. The cervical third, until a depth of 7 mm, was prepared with GT system instruments (Dentsply/Tulsa Dental, Tulsa, OK, USA). A stopper was placed on the instrument to limit the action of the file only in the cervical area. Subsequently, canals were submitted to biomechanical preparation with rotary K3 system instruments (SybronEndo, Glendora, CA, USA) using a crown-down sequence as follows: 30/.06, 25/.06, 20/.06, 25/.04, 20/.04, 30/.02, 35/.02, and 40/.02. At each change between instruments, canals were irrigated with 2 ml of 1% sodium hypochlorite using a disposable plastic syringe and NaviTip needles (Ultradent Products Inc., South Jordan, UT, USA). A final irrigation was performed with 2 ml of 17% EDTA for 5 min, followed by 2 ml of 1% sodium hypochlorite and then by 10 ml of distilled water. The root canals were dried with absorbent paper points (Tanari Industrial Ltd, Manacapuru, Brazil).

Each group was subdivided into four subgroups (n = 8) according to the endodontic sealer: A: unfilled; B: Endofill (Dentsply-Maillefer, Petropolis, Brazil) and gutta-percha (Tanari, Manacapuru, Brazil); C: AH Plus (De Trey Fréres, AS, Zurich, Switzerland) and gutta-percha; and D: Epiphany SE and Resilon (Penton Clinical Technologies, Walingford, CT, USA).

The filling materials were manipulated as per the manufacturers' instructions. The obturation was performed using the lateral condensation technique followed by removing 2 mm of the material with heated pluggers and vertical compaction. In the group filled with the Epiphany SE system, the sealer was photoactivated for 40 s at a distance of 10 mm from the cervical root surface. Root canal entrances were then sealed with non-eugenol temporary material (Coltosol; Vigodent, Rio de Janeiro, Brazil). All specimens were radiographed to verify the quality of obturation. Roots were stored at 37°C and 95% humidity for the duration of the sealer setting time.

To prevent transverse root fracture at the acrylic resin, a 2-mm wear was performed in the lingual portion of the root (12) using a diamond cylindrical bur (KG Sorensen). Roots were centralized in a parallelepiped-shaped base with wax in the apical portion so they could be kept in a vertical position. The root part projected out of the matrix presented a length of 6 mm. Subsequently, the specimens were embedded in autopolymerized acrylic resin (Classic JET, São Paulo, Brazil).

To ensure that the specimens remained at the established position during the compression test, the specimens were adapted in a stainless steel base developed for this purpose. This set was positioned in an Instron 4444 Universal Testing Machine (Instron Corporation, Canton, MA, USA). A force was applied at the junction of the buccal wall and the root canal entrance at 45° to the horizontal plan. A stainless steel tip was used at a crosshead speed of 1 mm per minute until fracture. The fracture moment was determined when there was a sudden drop in force observed on the display of the universal testing machine. The force required to fracture was recorded in Newtons (N).

Afterward, the fragments were analyzed with a 4× stereoscopic magnifying glass (Stemi 2000-C; Zeiss, Wetzlar, Alemanha) to assess the presence and location of fractures, which were classified as either transverse (straight across the tooth), longitudinal (following the long axis of the tooth) or oblique (diagonal to the tooth's long axis).

The obtained data were statistically analyzed and were normally and homogeneously distributed. Two-way analysis of variance (ANOVA) was performed to analyze the results, and Tukey's test was applied, when necessary, in cases where ANOVA revealed significant differences. The statistical analyses were performed with BioEstat 5.0 (Sociedade Civil Mamirauá, Belém, PA, Brazil) at a significance level of 5%.

Results

ANOVA did not reveal significant difference between the sealers (P = 0.228), and thus, there was no significant disparity in root fracture resistance. The mean forces for the different sealers were the following: unfilled: 189.1 ± 66.3 N, Endofill and gutta-percha: 186.3 ± 61.0 N, AH Plus and gutta-percha: 159.7 ± 69.9 N, and Epiphany SE and Resilon: 176.7 ± 55.2 N.

Conversely, a significant difference was demonstrated for the taper used in the cervical preparation (P = 0.009). The roots prepared with the highest taper files (#70/.12) were more susceptible to fracture and were statistically different from those with no cervical preparation (P < 0.05) but were similar to the roots prepared with files with #30/.10 and #30/.08 (P > 0.05) tapers. The specimens without cervical preparation had superior values for fracture resistance, were similar to the group prepared with the #30/.08 taper (P > 0.05), and were different from the others (P < 0.05) (Table 1).

Analysis of the fracture site revealed a predominance of longitudinal fractures in the cervical third. Transverse fractures were observed in the middle third of the specimens without cervical preparation. Longitudinal fractures in the middle third were predominant in the group prepared with a #70/.12 taper file. Oblique fractures were visualized in the cervical and middle third. The percentage of the fracture sites for each endodontic sealer is shown in Table 2.

Discussion

Cervical preparation contributes toward establishing an appropriate anatomic diameter of the root canal (12, 13) and determines a stable working length. Additionally,

Table 1. Mean values (standard deviation) of root resistance to fracture for each type of cervical preparation, expressed in N

Cervical preparation	Mean (SD)
No cervical preparation (GI)	205.38 (77.5) a
#30/.08 (GII)	185.21 (70.8) ab
#30/.10 (GIII)	164.80 (48.9) b
#70/.12 (GIV)	156.78 (41.4) bc

Same letter indicate statistical similarity (P < 0.05).

Table 2. Fracture sites in each group (%)

	Transverse			Longitudinal			Oblique		
Cervical preparation	C	M	A	C	M	A	C	M	A
No cervical preparation									
No filling	–	12.5	–	–	87.5	–	–	–	–
Endofil	–	–	–	12.5	87.5	–	–	–	–
AH Plus	–	–	–	87.5	–	–	–	12.5	–
Epiphany	–	12.5	–	25	62.5	–	–	–	–
#30/.08 taper									
No filling	–		–	87.5	–	–	12.5	–	–
Endofil	–		–	100	–	–	–	–	–
AH Plus	–		–	87.5	–	–	12.5	–	–
Epiphany	–		–	100	–	–	–	–	–
#30/.10 taper									
No filling	–		–	100	–	–	–	–	–
Endofil	–		–	87.5	12.5	–	–	–	–
AH Plus	–		–	87.5	12.5	–	–	–	–
Epiphany	–		–	87.5	12.5	–	–	–	–
#70/0.12 taper									
No filling	–		–	25	75	–	–	–	–
Endofil	–		–	–	87.5	–	12.5	–	–
AH Plus	–		–	75	25	–	–	–	–
Epiphany	–		–	–	87.5	–	12.5	–	–

C, cervical third; M, middle third; A, apical third.

this procedure can facilitate the action of endodontic instruments in the apical third (14), allowing for the effective cleaning of this region (15, 16). A suitable preparation of the cervical third enables direct access of the instrument within the canal, thereby decreasing possible accidents during the biomechanical preparation (17), proper penetration of irrigating solutions in the apical third (18), and a satisfactory root obturation (19).

The results of this study reveal that when the cervical preparation was performed with the highest taper (#70/.12), the roots were more susceptible to fracture, in contrast to those that did not receive cervical preparation. This outcome corroborates the findings of Tamse (20) and Zandbiglari et al. (3), who affirmed that the excessive use of rotary instruments during the radicular canal preparation may weaken the root. These results could be attributed to the wear of the intraradicular dentin in the cervical region promoted by the #70/.12 instrument, thereby changing the configuration of the root and weakening the dental structure. Although instruments with taper #70/.12 are not clinically indicated for the preparation of lower incisors, this taper was used in this study to simulate an extreme condition of tooth wear.

Another factor that can have contributed to the increase in fracture susceptibility is a possible loss of dentin moisture as a result of root canal treatment, yielding a consequent decrease in its resilience (21).

However, it was verified that the fracture susceptibility of roots prepared with #30/.08 instruments was similar to those not submitted to cervical preparation, suggesting that the quantity of dentin lost with this taper did not change the configuration of the root structure. Therefore, it could be extrapolated that #30/.08 instruments did not increase the susceptibility of a root to fracture. Nevertheless, further studies are required to confirm that the cervical wear using the #30/.08 taper allows for the clinical conditions to determine the anatomical diameter (12, 13), to guarantee the penetration of irrigating solutions (18), and to allow for the effective cleaning of the apical third (15, 16).

In regard to the endodontic sealers, the results revealed that none increased the root resistance to fracture. Although the new generation of methacrylate resin-based sealers (i.e., Epiphany SE) and the self-etching primers could improve the adhesion process, thereby contributing to an increase in the root fracture resistance (22), this was not observed in the study. One explanation could be the difficulty in photoactivating the sealer along the entire length of the root, leading to incomplete polymerization and the presence of residual monomers, especially in the deep region, with an associated decrease in the adhesive force to the dentin. Additionally, the presence of oxygen in the dentin walls and the tubules may impair sealer polymerization at the interface with dentin (23), which increases the susceptibility of roots to fracture.

Another aspect related to the inability of resin-based cements to increase the root resistance to fracture is limited creeping of the resinous sealer that is polymerized after the insertion into radicular canal that results in failures at the sealer/dentin interface (24). The shrinkage polymerization stress along the dentin/sealer interface may cause debonding of the material (25). The bonding capacity of resinous endodontic sealers may also be influenced by the very high C-factor of root canals that contributes to failures in the sealing of the filling material (26). In addition, the low Resilon module of elasticity does not favor the formation of a mechanically homogenous unit with the radicular dentin (27).

Despite the fact that the AH Plus cement has a creep capacity, high polymerization time, and better ability to penetrate microirregularities, all of which favor adhesiveness (28), it was not able to enhance root resistance to fracture, corroborating the findings of Apicella et al. (29), Cobankara et al.(30) and Stuart et al. (31).

Endofill is a zinc-eugenol-based sealer with rosin in its composition that releases ions, which are responsible for the electrical affinity and bonding capacity between cement and dental substrate. Considering that the dentin presents a high concentration of organic substances, the electrostatic interactions become compromised, resulting in a reduction of adhesion to the dentin (32). Such properties could explain the lack of increased resistance to fracture.

Concerning the location of fractures observed in this study, most of them occurred in the mesiodistal direction, parallel to the long axis of the tooth, in the radicular surface/acrylic material interface, which are in agreement with results reported by Zandbiglari et al. (3). The direction of the force application may influence the direction of the fractures because fractures toward the buccolingual region are usually observed in studies applying a force vertically (5, 33). The absence of fractures in the apical third may be related to the fact that specimens were embedded in a rigid material, which did not allow for stress propagation beyond the radicular surface/acrylic resin interface (34) that became the area of maximum force concentration.

In view of these results and the research-based evidence discussed, it is relevant to establish a minimum wear of the inner root dentin in the cervical region to achieve the objectives of biomechanical preparation and obturation without increasing susceptibility to root fracture. Even though the potential for resin-based sealers to reinforce a weakened tooth structure was not confirmed in this study, further investigations should be performed to improve adhesive systems and to decrease the risk of root fracture inherent to endodontic therapy.

In conclusion, a high level of dentin wear promoted during the cervical preparation increased the fracture susceptibility of roots. The endodontic sealers tested did not influence the fracture resistance of root-filled teeth. Over-preparation of the cervical area overcomes any potential strengthening a resin sealer can provide.

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