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ORIGINAL ARTICLE

Fracture resistance of roots with simulated internal resorption defects and obturated using different hybrid techniques

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KEYWORDS
biodentine;
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Abstract *Background/purpose:* Teeth with internal resorption are susceptible to fracture because of the remaining thin dentinal walls. The aim of this study was to investigate the fracture resistance of roots with simulated internal resorption cavities and obturated with different hybrid techniques.
Materials and methods: Seventy single root canals were instrumented. On the coronal half of the roots, standardized internal cavities with a length of 8 mm were created. The apical 6 mm of the 60 root canals were filled with AH Plus sealer and gutta-percha cones. Then, 80 roots were divided into four experimental groups and two control groups according to the internal cavity obturation: Group 1, AHPlus sealer + high-temperature thermoplasticized injectable gutta-percha; Group 2, DiaRoot Bioaggregate; Group 3, Biodentine; Group 4, MTA Fillapex; Group 5, instrumented, but not obturated roots; Group 6, intact roots. A compressive vertical loading at a speed of 1 mm/min was applied to the roots. The forces when the fracture occurred were statistically analyzed with one-way analysis of variance and *post hoc* Tukey test.
Results: Biodentine group showed statistically higher resistance to fracture than the other experimental groups ($P < 0.05$).
Conclusion: Filling the internal resorption cavities with thin dentinal walls using Biodentine may provide strength to the tooth structure more than the other calcium silicate-based materials.

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Introduction

Vertical root fracture (VRF) that occurs during or after endodontic treatment is a common failure with a poor prognosis. VRF can result from many factors including excessive loss of tooth structure during restorative and endodontic procedures, and forces generated from root canal instrumentation and obturation.[1,2] Therefore, root canal filling materials that have a high reinforcing capacity are recommended to fill the weakened roots to avoid fractures.[3,4]

Internal root resorption is a pathological process leading to the progressive destruction of dentine and compromising the tooth structure.[5] Thermoplasticized gutta-percha is preferred because of its flowability to fill the irregular defects resulting from internal root resorption. However, when the root becomes severely weakened with a risk of perforation, a hybrid technique is suggested, where the apical part of the root canal is filled with gutta-percha and the resorption area with a biocompatible material such as mineral trioxide aggregate.[6,7]

DiaRoot Bioaggregate is a calcium silicate-based sealer, and most of its constituents are similar to those of MTA with several modifications.[8] It was suggested that DiaRoot Bioaggregate is free of aluminum and contains tantalum oxide instead of bismuth oxide contrary to the conventional MTA.[8] MTA Fillapex is another MTA-based salicylate resin root canal sealer and is composed of mineral trioxide aggregate, salicylate resin, bismuth, and nanoparticulated silica. MTA Fillapex elicits similar tissue reactions with MTA. Moreover, MTA Fillapex is suggested to act similar to MTA when it is used under clinical conditions.[9] Although DiaRoot Bioaggregate and MTA Fillapex both include mineral trioxide aggregate in their composition, the physical behaviors such as reinforcing capacity may vary because of the different additional substances that they contain.

Calcium silicate-based materials are proposed to have high biocompatibility and increased sealing ability.[10] Therefore, they are indicated for use in many clinical applications including obturation of root resorptions and perforations.[11] Biodentine is a recently introduced calcium silicate-based material containing tricalcium silicate, calcium carbonate, zirconium oxide, and a water-based liquid. Although one of its clinical applications is internal root resorption according to the manufacturer, its appropriate use has not been evaluated in such clinical cases. Biodentine was suggested to have better bonding ability compared to the other calcium silicate-based cements.[12,13] However, there is limited information about its reinforcing capacity on the structurally compromised roots with thin dentinal walls.[14]

The aim of this study is to evaluate the fracture resistance of roots with simulated internal resorption cavities and obturated with different hybrid techniques.

Materials and methods

Mandibular premolar teeth that were extracted because of periodontal reasons were selected. The mesiodistal diameter of the teeth was measured at the cementoenamel junction using a digital caliper, and those with similar mesiodistal diameters (5.0 ± 0.5 mm) were included. The teeth having caries, root cracks, immature roots, and more than one canal were excluded. A total of 80 teeth meeting the criteria were stored in distilled water prior to the start of the experiment. Teeth were decoronated at the cementoenamel junction using a high-speed diamond bur under water spray to obtain a standard root length of 14 mm. A conventional endodontic access was prepared on the 70 root canals. The working length was established 1 mm short of the apical foramen with a size of 10 K file. Seventy root canals were instrumented with ProTaper rotary instruments to a master apical size of F3. The root canals were copiously irrigated using 3 mL 2.5% NaOCl during instrumentation. On the coronal half of 70 roots, standardized internal cavities with a length of 8 mm and a diameter of 2.3 mm were created using diamond round burs with the same diameter (Figure 1A). A final irrigation was applied for 1 minute using 2 mL 18% EDTA (Ultradent, South Jordan, UT, USA) in order to eliminate the smear layer. The root canals were then rinsed with 5 mL distilled water and dried with paper points. The apical 6 mm of the 60 root canals were filled with AH Plus sealer (Dentsply De Trey, Konstanz, Germany) and gutta-percha cones using cold lateral condensation technique (Figure 1B). Then, 80 roots were divided into four experimental groups ($n = 15$) according to the obturation technique used in the coronal internal cavities, and two control groups ($n = 10$) as detailed below.

Group 1, AH Plus sealer + high-temperature thermoplasticized injectable gutta-percha (Obtura 2; Obtura Spartan, Fenton, MO, USA): AH Plus sealer that was mixed according to the manufacturer's instructions was slightly applied to the root canals. The working temperature of Obtura 2 system was adjusted to 160°C. The silver needle of the Obtura 2 gun was placed 5–6 mm of the internal resorption cavity. The plasticized gutta-percha was injected until gutta-percha was observed in the canal orifice. The gutta-percha was compacted gently with an endodontic plugger.

Group 2, DiaRoot Bioaggregate (DiaDent, Burnaby, BC, Canada): The powder of DiaRoot Bioaggregate was mixed with sterile water in a 3:1 powder/liquid ratio. Then the cement was incrementally placed in the cavities with hand pluggers and condensed.

Group 3, Biodentine (Septodont, Saint Maur-des-Fosses, France): According to the manufacturer's instructions, five drops of the liquid was poured into the powder containing capsule. The capsule was closed and triturated for 30 seconds on a mixing device. The Biodentine was collected and incrementally placed in the cavities with a hand plugger (Figure 1C).

Group 4, MTA Fillapex (Angelus, Londrina, Brazil) + high-temperature thermoplasticized injectable gutta-percha: MTA Fillapex that was premixed in an injectable form was applied to the simulated internal defects via its intracanal tip. Then high-temperature thermoplasticized gutta-percha was injected to the cavities by its Obtura 2 gun needle as in Group 1. The gutta-percha in the canal orifice was compacted with a hand plugger.

Group 5, Negative control: This group consisted of instrumented, but not obturated, roots.

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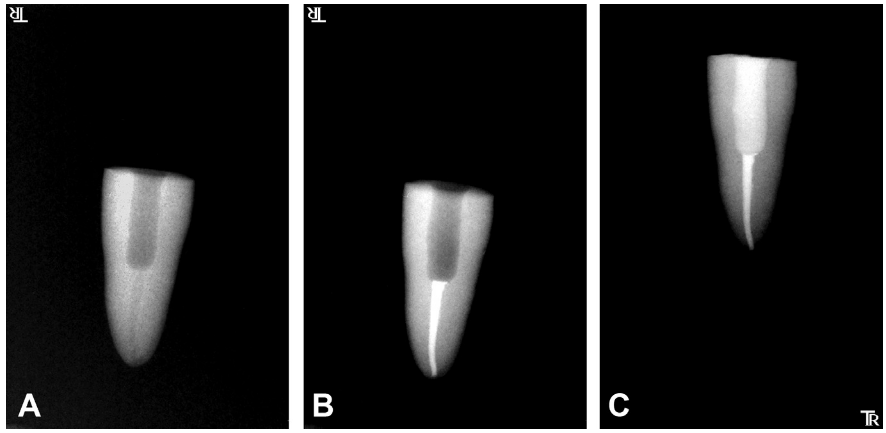

Figure 1 (A) Periapical radiograph of an instrumented root canal with simulated internal resorption cavity. (B) Radiographic image of the root canal with only apical filling. (C) Filling of the internal defect using Biodentine.

Group 6, Positive control: The roots in this group were not instrumented or obturated, and remained intact.

All specimens were stored in 100% humidity at 37°C for 48 hours to allow complete setting of the sealers prior to mechanical testing.

The apical 7 mm of all roots was covered with a thin layer of polyvinyl siloxane impression material to provide a layer simulating periodontal membrane. Then the roots were mounted vertically in a self-cure acrylic resin blocks (Meliodent, Bayer Dental, Leverkuser, Germany), exposing 7 mm of the coronal parts. Acrylic blocks including specimens were placed in a Universal Testing Machine (Lloyd LR 30 K, Fareham, England). A compressive vertical loading at a speed of 1 mm/min was applied with spherical tips contacting the entire surface of the roots. The force when the fracture occurred was recorded in Newtons. The data were statistically analyzed with one-way analysis of variance and *post hoc* Tukey test with a significance level of 0.05.

The type of fracture was assessed for each specimen using the modification of the following scale described by Alharbi et al[15]: the root fracture above the level of acrylic resin was classified as supracrestal root fracture; the root fracture below the level of acrylic resin was defined as subcrestal root fracture; the fracture line extending along the long axis of the tooth was categorized as vertical fracture.

Results

The means, standard deviations, as well as the minimum and maximum values of the fracture strength test are shown in Table 1. There was a statistically significant difference between the groups according to the one-way analysis of variance ($P < 0.05$). *Post hoc* Tukey test revealed that the Biodentine group had a statistically higher resistance to fracture compared with the other experimental groups ($P < 0.05$). The lowest fracture load values were derived from AH Plus + Obtura 2 combination among the experimental groups, for the internal resorption cavity obturation. The roots obturated with DiaRoot Bioaggregate showed higher structural resistance than with MTA Fillapex + Obtura 2, although the difference was not statistically significant.

The majority of the fractures after loading were vertically or obliquely oriented and mainly located above the level of acrylic resin base (supracrestal root fracture). The number of fracture patterns observed in the samples is shown in Table 2.

Discussion

In the internally resorbed teeth, the root canal walls become thin, making the roots prone to fracture. Therefore, the materials that were suggested to have reinforcing capacity should be preferred for filling the areas with thin dentinal walls to prevent fractures.[16] Specifically, when restoring the perforating internal resorption cases by using hybrid technique, MTA is commonly the material of choice to fill the resorbed area and seal the perforation because of its sealing ability and mechanical strength.[6] Obturation of perforating internal resorption cavities is also one of the clinical applications of Biodentine according to the manufacturer. Therefore, in the present study, we have used

Table 1 Mean, standard deviation, minimum and maximum values of fracture resistance (in Newtons) for the experimental and control groups.

Groups	N	Mean (SD)	Minimum	Maximum
AH Plus + Obtura II	15	505.8 (110.4) ^{a,b}	307.0	738.0
DiaRoot Bioaggregate	15	721.7 (180.5) ^{c}	430.0	991.0
Biodentine	15	1025.5 (186.9) ^{d}	751.0	1416.0
MTA Fillapex + Obtura II	15	614.6 (166.8) ^{b,c}	420.0	923.0
Negative Control	10	313.3 (121.3) ^{a}	150.0	470.0
Positive Control	10	986.1 (181.7) ^{d}	712.0	1278.0

Different superscript letters indicate the statistical differences between the groups.
N = number; SD = standard deviation.

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Table 2 Types of fractures observed in the roots after vertical loading.

Groups	N	Fracture patterns		
		Supracrestal root fracture	Subcrestal root fracture	Vertical fracture
AH Plus + Obtura II	15	11	3	1
DiaRoot Bioaggregate	15	10	4	1
Biodentine	15	12	3	0
MTA Fillapex + Obtura II	15	10	4	1
Negative Control	10	8	2	0
Positive Control	10	4	4	2

Biodentine in the simulated internal defects with thin dentinal walls mimicking perforating internal resorptions.

It was suggested that calcium silicate-based materials chemically bond to root canal dentine.[10] Although the positive correlation between bond strength and fracture resistance is not clear, it was generally accepted that successful adhesion of the materials to the root dentine increases their reinforcing effect.[16] Biodentine was reported to release larger amounts of calcium compared to the conventional MTA, which may lead to the higher formation of interfacial layer and tag-like structures.[17] This property could increase the bonding ability of Biodentine.[12,17] In addition, Grech et al[18] reported higher washout values and superior mechanical properties of Biodentine compared to the Bioaggregate. In the present study, higher fracture resistance results obtained from the Biodentine group could be attributed to these superior qualities of the material. In spite of the studies confirming the stronger bonding capacity of Biodentine compared to other calcium silicate-based materials,[12,13] there is limited information evaluating its reinforcing effect.[19,20]

In the present study, DiaRoot Bioaggregate reinforced the roots with artificial internal defects better than AHPlus + Obtura 2. This finding is similar to those reported by other studies, in which the fracture resistance of roots filled with White MTA was higher compared to AHPlus.[14] We have used DiaRoot Bioaggregate instead of conventional MTA, because of their similar compositions. However, DiaRoot Bioaggregate was proposed to show several chemical differences such as aluminum-free composition and tantalum oxide content.[8] It is not clear if this modification has affected its physical behaviors such as reinforcing ability as we did not compare the MTA and DiaRoot Bioaggregate in terms of strengthening effect.

The fracture resistance values of DiaRoot Bioaggregate were higher than those of MTA Fillapex, although it was not statistically significant. Filling the internal resorption cavities entirely with only DiaRoot Bioaggregate may have increased homogeneity and improved the fracture resistance. MTA Fillapex was suggested to be a more suitable sealer when used with warm gutta-percha obturation techniques.[21] Therefore, in the present study, MTA Fillapex has been used as a sealer and thermoplastic gutta-percha as a core material using Obtura 2 in the internal defects. Tanalp et al[22] showed that MTA Fillapex did not improve the fracture resistance of thin-walled roots more than the AH Plus did. This finding is in agreement with our findings despite the differences between the experimental designs. They performed a simulated immature tooth model instead of internal resorption cavities as we did in the present study.

The orientation of the applied forces varies within the studies.[3,20,23] Because mandibular premolar and molar teeth sustain vertical forces more than lateral forces during root canal obturation and occlusion, we have used vertical forces on the premolar teeth. Therefore, the majority of the fracture lines were vertically oriented. The fractures were mainly located in the coronal parts of the roots (supracrestal) because of the location of the cavities with fragile dentinal walls and did not generally extend below the acrylic resin block.

The internal root resorption may occur in any area of the root canal system.[5] We have simulated internal resorption defects in the coronal portion of the root in order to ease manipulation. However, the real clinical resorption defects have more irregular shapes compared to the ones that are presented in our study. We have created cavities with a smoother outline using round burs to obtain standardization.

The compressive loading test is commonly used to assess the reinforcing ability of the materials. However, they provide limited information about the stress distribution of teeth during application of loads.[24] The combination of the destructive mechanical tests with nondestructing analysis such as finite element may be more valuable during evaluation of the stresses generated within the tooth structure.[24]

It was concluded that filling the internal resorption cavities with thin dentinal walls using Biodentine may provide strength to the tooth structure more than the other calcium silicate-based materials. Therefore, Biodentine may be used as an alternative to MTA in the hybrid technique when restoring the internal resorbed tooth with a risk of perforation.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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