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Original Article

Fracture resistance of immature teeth filled with mineral trioxide aggregate, bioaggregate, and biodentine

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ABSTRACT

Objective: The purpose of this study was to evaluate fracture resistance of teeth with immature apices treated with coronal placement of mineral trioxide aggregate (MTA), bioaggregate (BA), and Biodentine. **Materials and Methods:** Forty-one freshly extracted, single-rooted human premolar teeth were used for the study. At first, the root length was standardized to 9 mm. The crown-down technique was used for the preparation of the root canals using the rotary ProTaper system (Dentsply Maillefer, Ballaigues, Switzerland) of F3 (30). Peeso reamer no. 6 was stepped out from the apex to simulate an incompletely formed root. The prepared roots were randomly assigned to one control (n = 5) and three experimental (n = 12) groups, as described below. Group 1: White MTA (Angelus, Londrina, Brazil) was prepared as per the manufacturer's instructions and compacted into the root canal using MAP system (Dentsply Maillefer, Ballaigues, Switzerland) and condensed by pluggers (Angelus, Londrina, Brazil). Group 2: The canals were filled with DiaRoot-BA (DiaDent Group International, Canada). Group 3: Biodentine (Septodont, Saint Maur des Fosses, France) solution was mixed with the capsule powder and condensed using pluggers. Instron was used to determine the maximum horizontal load to fracture the tooth, placing the tip 3 mm incisal to the cementoenamel junction. Mean values of the fracture strength were compared by ANOVA followed by a *post hoc* test. $P < 0.05$ was considered statistically significant. **Results:** No significant difference was observed among the MTA, BA, and biodentine experimental groups. **Conclusion:** All the three materials tested, may be used as effective strengthening agents for immature teeth.

Key words: Fracture resistance, immature teeth, root-end filling materials

INTRODUCTION

Dentin thickness is one of the most important factors determining the resistance to fracture of teeth. The tissue loss of the tooth reduces the fracture resistance toward occlusal or traumatic forces.[1] Endodontic treatment of immature teeth has been a problem due to their wide, open apices, and thin dentin walls.[2,3] When regenerative treatment has failed or not considered as an option, apical barrier techniques are still used quite often in the treatment of such teeth.[4,5]

Application of calcium hydroxide to the root canal system to promote the formation of an apical barrier is the conventional treatment in these clinical situations.[6-8] However, the long-term calcium hydroxide treatment requires multiple visits, patient adaptation problem, microleakage between the visits and an enhanced risk of root fractures.[9,10] Such drawbacks were addressed by the single visit apexification treatment with mineral trioxide aggregate (MTA).[11-14]

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MTA consists of tricalcium oxide and other mineral oxides such as tricalcium silicate, silicate oxide, and tricalcium oxide.[15] MTA is biocompatible, less cytotoxic, has antimicrobial properties, offers low microleakage, and can set in the presence of blood or moisture.[16,17] Although MTA is a suitable material for clinical use, it has certain disadvantages such as a prolonged time for setting, difficulty in handling, and the probability of discoloration.[18]

Recently, new calcium silicate–based materials, such as Biodentine (Septodont, Saint-Maur-des-Fossés, France), and Bioaggregate (BA; Innovative BioCeramix, Vancouver, Canada) have been reported to overcome the drawbacks associated with MTA.[19,20]

These materials trigger the release of calcium hydroxide in a solution that upon contact with the tissue fluids forms hydroxyapatite.[21] Biodentine contains zirconium oxide while BA contains tantalum oxide for radiopacifier. Both the materials also contain tricalcium silicate.[19,21]

Studies focused on the reinforcing effect of different root canal obturation methodologies differ in terms of teeth selection, simulation of open apices, preparation of experimental models, and the direction of force applied during fracture testing.[8,22] Several materials including composite resin and different postsystems have been used to strengthen immature teeth.[23-25] Based on the results of these studies, it appears that composite resin bonded to the canal walls has great potential to increase fracture resistance.[2,3,23]

The ability of MTA to strengthen the tooth structure has been studied with controversial results.[10,26,27] White *et al*.[28] showed a weakening of dentinal structure in short-term and attributed this effect to the structural alteration of proteins caused by the alkalinity of MTA.

Furthermore, there is limited information on the strengthening capacity of novel tricalcium silicate based root-end filling materials. The aim of this study was to evaluate the fracture strength of immature teeth upon coronal placement with MTA, Biodentine, or BA.

MATERIALS AND METHODS

Forty freshly extracted, single-rooted human premolar teeth without decay, crack or fracture were selected for the current study. They were stored in saline solution to prevent dehydration until further use. Five teeth served as controls, and no further treatment was given to them. The roots were cut from the cementoenamel junction (CEJ) to standardized 9 mm the root length. Standard occlusal access cavities were prepared using a water-cooled round bur in a high-speed handpiece (NSK, Japan), and working lengths were determined visually by subtracting 1 mm from the point at which a size 15 K-file just exited the apical foramen. The canals were instrumented by ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) rotary nickel-titanium instruments using a crown-down technique to attain a master apical file size of a finishing file 30 (F3). The canals were irrigated with 5.25% NaOCl (Sultan Healthcare Inc., Englewood, USA) during preparation. Peeso reamers (No. 1–6) were used and the peeso reamer no. 6 was stepped out from the apex to simulate an incompletely formed root. The smear layer was removed by using 2 ml 17% ethylenediaminetetraacetic acid. The specimens were irrigated with distilled water and dried with paper points. The prepared specimens were randomly assigned into the following groups: Three experimental (n = 10) and one control (n = 10): Group 1 (MTA): White MTA (Angelus, Londrina, Brazil) powder was mixed with distilled water according to the manufacturer's instructions, inserted into the root canal using MAP system (Dentsply Maillefer, Ballaigues, Switzerland) and condensed by pluggers (Angelus, Londrina, Brazil). The teeth were filled fully from the apical foramen to coronal as described by Tuna *et al*.[29] Group 2 (BA): The canals were filled with BA (DiaDent Group International, Canada). The BA was prepared as per the protocol provided with the kit. The teeth were filled from the coronal access using MAP system and pluggers. Group 3 (Biodentine): Biodentine (Septodont, Saint Maur des Fosses, France) liquid from a single-dose container was emptied into a powder-containing capsule and mixed for 30 s at 4000–4200 rpm. It was condensed using pluggers. The teeth were incubated at 37°C and 100% humidity for 7 days.

Acrylic resin blocks, 10 mm high and 20 mm wide, were prepared. All the roots were embedded in a vertical direction in the acrylic blocks, leaving a distance of 2 mm between the top of the acrylic and the cement – enamel junction. The Instron Universal Testing Machine (Lloyd-LRX; Lloyd Instruments, Fareham, UK) was used for application from the lingual direction. The tip was placed 3 mm incisal to the CEJ, and the samples were loaded at a crosshead speed of 5.0 mm/min as applied by Milani *et al*.[30]

and Schmoldt *et al*.[31] The peak load to fracture was recorded in Newtons.

Statistical analysis

Mean values of fracture strength were compared by ANOVA followed by a *post hoc* Tukey test. All the analyses were done using the SPSS 15.0 (IBM Corp., Armonk, NY, USA) for Windows program. The significance level was set at $P < 0.05$.

RESULTS

Table 1 shows the mean fracture strengths and standard deviation obtained in the groups. Significant variations ($P < 0.05$) between the groups were observed in ANOVA test. *Post hoc* Tukey analysis showed that there were significant differences among the experimental and the control groups. The MTA group showed the highest fracture resistance, followed by BA and Biodentine. There was significant difference between the experimental and the control groups. However, no significant difference was found among the MTA, BA, and Biodentine experimental groups.

DISCUSSION

Immature teeth are more fragile than the mature teeth due to their thin dentin walls, thus, pose difficult for the clinicians.[26] In spite of the feasibility of treatment of the open apex, immature teeth remain sensitive to fracture, especially in the cervical area.[23] Therefore, a material with reinforcing effect must be chosen in such cases, which may be manipulated easily, could prevent microleakage, be removed when necessary, and can adhere consistently to the dentin walls.[32]

Various materials including composite resins, resin-reinforced glass ionomers, resin-based root canal fillings (Resilon), different postsystems, and different root-end filling materials, such as MTA and BA have been used to reinforce the immature permanent teeth.[23,29,33]

In this study, the efficiency of MTA, BA, and Biodentine on root fracture resistance was evaluated

Table 1: Mean and standard deviations of different experimental or control groups ($P \leq 0.05$)

	n	Mean (Newton)	SD	Minimum	Maximum
Control	10	470.7364	25.13767	428.72	492.95
MTA	10	568.3618	91.78048	446.81	713.46
Bioaggregate	10	481.6923	126.77524	381.16	710.24
Biodentine	10	529.0284	90.73658	382.14	668.10

SD: Standard deviation, MTA: Mineral trioxide aggregate

in human simulated immature premolar teeth with identical diameter and length. Standardization of teeth is recommended by many authors in this fracture research.[34,35]

The roots were put into acrylic block for homogeneous distribution of the force. The influence of the periodontium was ignored in this study. Therefore, the root length was standardized to 9 mm, and the apex was enlarged using peeso reamers (No. 1–6). Stuart *et al*.,[32] Tanalp *et al*.,[8] and Seto *et al*.[36] used a similar methodology for preparation of root canals.

In such studies, researchers apply force from different angles to the teeth.[8,30,37] A 90° angle was applied for placement of the teeth into the testing machine as previously demonstrated by Tuna *et al*.[29] Although the force applied in *ex vivo* studies cannot completely simulate the clinical situations, standardizing the force in all of the study groups makes it possible to compare the strengthening effect of materials tested.[30]

Our results showed that the teeth without any filling (control group), showed a lower fracture strength in comparison to the MTA, BA or Biodentin filled teeth (three experimental groups). All the materials tested, considerably strengthened the immature teeth. However, no major differences were observed amongst the three materials, which may be attributed to the similar composition and structure of MTA, BA, and Biodentine.

White *et al*.[28] reported that MTA and sodium hypochlorite reduce the fracture susceptibility of bovine dentin by 33% and 59%, respectively compared to the control group. Andreasen *et al*.[10] reported that MTA strengthens the cervical fracture resistance of immature sheep incisors more effectively than calcium hydroxide.

Milani *et al*.[30] conclude that MTA and calcium-enriched mixture cement exhibited a distinct reinforcing effect on immature teeth after 6 months. This result is consistent with the findings of our study. Tuna *et al*.[29] investigated the fracture resistance of immature teeth filled with BA and ProRoot MTA for long-term treatment and found, different from our results, superior fracture resistance when BA was used for root filling. We think that long-term application of BA may account for this result.

Biodentine is produced as a root-end filling material, like MTA, and has almost alike content as MTA, when it gets set.[38] The tag-like structures within the dentinal tubes may be responsible for adhesion of Biodentine with the dentinal tubes via micromechanical connection.[39] Until the present study, Biodentine was not used as a reinforcing material for immature teeth. However, a study by Guneser *et al*. demonstrated that Biodentine is more resistant to dislodgement forces than the MTA.[40] However, in the present study, Biodentine was less effective as a reinforcing material than MTA or BA.

A finite element analysis study showed that the materials with similar elastic modulus to dentin could reinforce the weak roots.[41] The elastic modulus of MTA is not available; however, the elastic modulus of Portland cement is around 15–30 GPa after 2 weeks.[30] Considering the elastic modulus of dentin which is about 14–18.6 Gpa,[41] the reinforcing effect of tricalcium silicate based materials may be explained by its similar elastic modulus to dentin.

CONCLUSION

Within the limitations of this study, all the selected materials were found effective for strengthening the weak structure of teeth. Biodentine, new silicate material, is an alternative material that should be considered when planning treatment for teeth that have immature apexes. Tricalcium silicate materials, when used for the treatment of immature teeth, may enhance their longevity in the mouth.

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Conflicts of interest
There are no conflicts of interest.

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