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Structural resistance in immature teeth using root reinforcements *in vitro*

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Abstract – The purpose of this study was to evaluate *in vitro* the efficacy of root reinforcements by light-cured composite resin or zirconium fiber post in simulated immature non-vital teeth. Fifty-six bovine incisors teeth were used for this study. The crown of each tooth was removed in the medium third to obtain a standard length of 30 mm. The specimens were divided into four groups ($n = 14$): G1) the root canals were instrumented and enlarged to simulate immature non-vital teeth and were reinforced with a light-cured composite resin using a translucent curing post (Luminex system); (G2) the specimens were instrumented, enlarged and they received root reinforcement with zirconium fiber post; G3 (positive control): they received similar treatment to the G1 and G2 groups, but did not receive root reinforcement; G4 (negative control): the roots were not weakened and did not receive reinforcement. Every tooth was submitted to compressive force using an Instron testing machine with an angle of 45° at a speed of 1 mm min^{-1} until the fracture. The results showed a markedly increased resistance to fracture in the G1 and G2 (122.38 and 122.08 kgf, respectively). Among the results of G1 and G2 there was not any significant difference ($P > 0.05$) but they were significantly different from the control groups ($P < 0.05$). The conclusion is that the use of root reinforcements with zirconiun fiber post or composite resin can increase significantly the structural resistance of the weakened teeth, decreasing the risk of the fracture.

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Dental impact injuries involve young adults and mainly children at school age (1) between 8 and 12 years old (2). These injuries can result in pulp necrosis of immature permanent teeth with incomplete root development, and consequently, with thin and weak root walls (3). The endodontic treatment in these cases reaches a very high success level when the apexification technique using calcium hydroxide is performed (4). On the contrary, Andreasen et al. (5) suggested that a calcium hydroxide dressing in the root canal for an extended time weakens the root structure. In this way, the remaining root walls, which are thin, particularly in the cervical region, present a very serious clinical problem. Should a second injury occur, teeth would be more susceptible to root fractures and preserving those teeth will be difficult (6, 7). For this reason, the use of reinforcement in these weak roots is necessary.

Several materials have been used with the aim of increasing the resistance of endodontically treated teeth. El-Khodery et al. (8) verified a resistance increase of the dental structure when the root canal was filled with composite resin. The use of composite resin in the root canal walls, as a way of strengthening the remaining dental structure can be a viable solution although it presents some problems. When the self-cured composite resin is used, the curing time cannot be controlled. On the contrary, when the light-cured composite resin is used, the problem consists on the curing of deep layers of this material. Four or 5 mm of thickness can result in an incomplete curing process because of the limited curing-light transmission through the material in the root canal. The system of distant curing light transmission (Luminex System; Dentatus Ltd, New York, NY, USA) attenuated this problem. In this system, a translucent curing post is used to assist in curing the deeper layers of resin allowing the use of resin as root reinforcement.

Considering the structural reinforcement of endodontic treated teeth, Yaman & Thorsteinsson (9) verified that Para-Post system posts are able to better distribute the strength, increasing dental resistance. Cohen et al. (10) related that Flexi-Post system used in root canals presents a good dental retention and stress distribution. Sirimai et al. (11) verified that prefabricated posts combined with the polyetilene fibers and composite cores improved resistance to dental fracture. Glass ionomer cement was also used as an auxiliary way to help teeth strengthening (12, 13).

There are few studies in the literature that give the importance and value to the resistance to fracture in traumatized and endodontically treated immature permanent teeth, and therefore there is little information about the variables that can increase the resistance of those teeth to new fractures (3).

The purpose of this study was to evaluate *in vitro* the dental resistance to fracture obtained by reinforcing the root canal walls with zirconium fiber post or composite resin, using weakened teeth to simulate those endodontically treated immature teeth.

Materials and methods

Specimens preparation

Fifty-six bovine incisor teeth, free of decay or fractures, were included in this study. The teeth were obtained from a slaughterhouse at São José dos Campos – SP-Brazil. These teeth were extracted just after the slaughter and maintained at −18°C until the use. For previous selection of the teeth, mesiodistal and buccolingual diameters were determined using a caliber at the cervical limit of the root. The average values obtained were 7 mm for mesiodistal and 9 mm for buccolingual.

The crowns were removed in the medium third with a water-cooled diamond bur to obtain a dental standard length of 30 mm. The coronary access was made with a diamond bur under high-speed water-spray cooled and the dental pulp was removed by Hedströen files no. 45 (Maillefer, MI, USA). The root canals were instrumented 1 mm short of the apex, using Kerr files until no. 80 (Maillefer, MI, USA). During preparation, the canals were irrigated with 1% sodium hypochlorite.

The 20 mm of entension related to the cervical and medium thirds of the roots were initially enlarged with Gates-Glidden burs (Maillefer, MI, USA) nos 3, 4, 5 and 6. After, to simulate an immature tooth, the root canal was enlarged with a tapered rounded bur no. 721 (KG Sorensen; KG Sorensen Ind Com Ltd, SP, Brazil) mounted on a low-speed handpiece, in the depth of 20 mm, to obtain dentinal walls thickness of ±2 mm in the cervical third. All specimens were buccolingual and mesiodistal radiographed to check the mentioned thickness (Fig. 1).

The 56 specimens were divided into four groups ($n = 14$), according to the root reinforcement performed, as follows:

Group 1: The 14 specimens had the cervical and medium third of the root canal (20 mm) reinforced by light-cured composite resin (THP; Dentsply Ind Com Ltd, Petrópolis, RJ, Brazil) using a translucent curing post (Luminex; Dentatus Ltd). Root dentinal walls were etched with 37% phosphoric acid for 15 s. Abundant rinsing with water and drying with paper points was performed. The light-cured bonding system (Prime & Bond 2.1; Dentsply Ind. Com. Ltd) was applied. The selected curing post (1.6 mm) was placed until a depth of 20 mm and the resin composite was inserted and cured through it for 60 s. The translucent post was then removed, remaining the composite resin structural reinforcement in the medium and cervical thirds of the roots. After, the root canal was obturated with gutta-percha cones and Sealer 26 cement (Destsply Ind. Com. Ltd) using the lateral condensation technique.

Group 2 (14 specimens): The apical 10 mm of the root was obturated with gutta-percha cones and Sealer 26 cement, leaving 20 mm length free for post space. The root reinforcement was performed with zirconium fiber post (Cosmopost; Ivoclar, Schaan, Liechtenstein, UK) cemented with

Fig. 1. Weakened tooth with root walls thickness of 2 mm in the cervical third to simulate immature tooth.

dual-cure resinous cement (Enforce; Dentsply Ind. Com. Ltd).

Group 3 (14 specimens): The root canals were instrumented, weakened and obturated with gutta-percha cones and Sealer 26 cement. This group did not receive root reinforcement (positive control).

Group 4 (14 specimens): The root canals were not instrumented and not weakened. This group did not receive root reinforcement (negative control).

In all specimens, the coronary access was sealed with glass ionomer cement (Vidrion R; SS White, Rio de Janeiro, RJ, Brazil).

Samples preparation

The roots were covered by a thin layer (0.2 mm) of rubber silicon adhesive (Flexite; Alba Ind. Quím, SP, Brazil) to simulate the periodontal ligament. Each tooth was mounted in acrylic block using a metallic mould (25 mm of diameter and 30 mm high). Self-curing acrylic resin was mixed and poured at dough stage in the metallic mould and the root portion was embedded in the resin in a centralized position. Five millimeters of the coronary portion were left out side the block.

For the adaptation of the specimens to the assay machinery, a cylindrical device was obtained. This cylinder presented a fitting that permitted the fixing of the specimens at an angle of 45° (Fig. 2), allowing the application by the Universal testing machine (Instron model 4331; Instron Corp., Canton, MA, USA).

Resistance to compression testing

All the specimens were submitted, after 1 week, to compression strength until the fracture. For this purpose, the specimens were fixed by screws to the structure of the device, maintaining an angle of 45° (Fig. 2) and the device was adapted to the base of the testing machine. The compressive force necessary to result in root fracture was determined with a head speed of 1 mm min^{-1}. Results were statistically evaluated using ANOVA and Tukey's test.

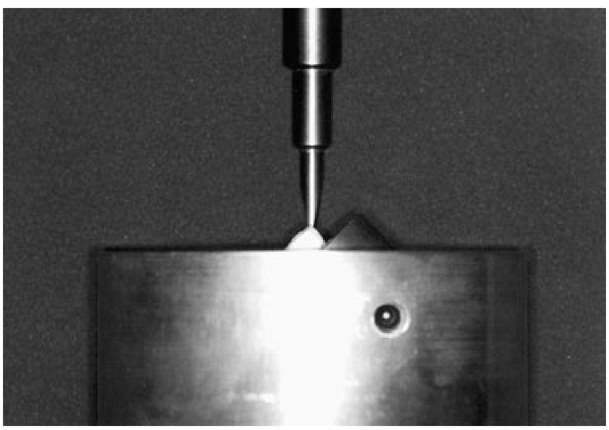

Fig. 2. Tooth submitted to compressive force using an Instron testing machine (45°).

Results

The Table 1 presents the mean of fracture resistance (in kgf) obtained through the compression testing and the standard deviation for each studied group.

Groups G1 (composite resin/Luminex) and G2 (Zirconium fiber/Cosmopost) presented fracture resistance similar among them ($P > 0.05$) and were significantly different from the control groups ($P < 0.05$). Group G4 (negative control) was significantly more resistant ($P < 0.05$) than groups G1, G2 and G3. Group G3 (positive control) and G4 (negative control) were statistically different among them ($P < 0.05$).

Discussion

In this study, an experimental model that simulates immature non-vital teeth with weakened dentinal walls was used. In order to create a wide root canal with thin dentinal walls, the root canal was enlarged with a tapered rounded drill for hand piece in low speed rotation no. 721 (KG Sorensen) in a depth of 20 mm, leaving approximately 2 mm of dentin between the prepared root canal and the outer root surface in the cervical third. Bovine incisors were used in this study because they allow the standardization of the sample. They were selected according to their mesiodistal and buccolingual dimensions in the cervical third in order to obtain 56 teeth with 7 mm of thickness in the cervical third of the root and to reduce variables to the different anatomical structures.

In immature teeth, a weakened dentinal wall represents a serious clinical problem, mainly if it is in the cervical area (3), because the dental element becomes susceptible to fracture (6, 7, 14). In agreement with the study of Cvek (15) the frequency of cervical root fractures was markedly higher in immature teeth than mature teeth and, among immature teeth, the frequency of fractures was dependent on the stage of root development and ranged from 77 to 28% in teeth with the least and

Table 1. Mean and standard deviation (kgf) of the different studied groups

Group	Mean (kgf)	SD
1 (composite resin/Luminex)	122.38	6.80
2 (Cosmopost posts)	122.08	8.95
3 (Positive control)	78.28	4.64
4 (Negative control)	133.06	11.29

the most developed roots respectively. In the present study, it can be observed that teeth with thin root walls were significantly more fragile than teeth with higher root thickness. Taking these values to clinical situations, it can be proved that teeth with incomplete root formation are more susceptible to root fractures than teeth with complete apex (3, 6, 7).

Several studies recommend the use of posts to reinforce endodontically treated teeth (8, 11, 16, 17, 18). Heydecke et al. (19) verified means of fracture resistance with zirconium fiber posts of 107.8 kgf and for titanium posts of 105.8 kgf. Although in the studies cited before, the remaining dental structure were not weakened to simulate immature teeth, their results are similar to those obtained in the present study, in which the use of root reinforcement with zirconium fiber posts increased significantly the resistance of these specimens to compression (122.38 kgf), reaching a fracture resistance similar of a tooth that was not weakened (Table 1). In this study it was used the zirconium fiber posts because of the good aesthetic results and the resistance to the compression presented in the researches of Zalkind & Hochman (20), Asmussen et al. (21) and Hochman & Zalkind (22).

The use of root reinforcement with composite resin using the translucent curing post (Luminex system), in the present study, increased significantly the resistance of the root dentinal walls in simulated immature teeth. These results were different from the obtained by Heydecke et al. (19), who verified that the composite resin did not increase the dental resistance to the compression tests. However, Katebzadeh et al. (3) observed all of the bonded resin techniques using a clear post system significantly strengthened the teeth against fracture, compared with the negative control group (teeth with thin dentinal walls that did not receive reinforcements). El-Khodery et al. (8) verified that teeth treated with dentin bonded all composite post and coronal filling had more resistance to compression at 45°, presenting an additional resistance of 59% in comparison with the group without root reinforcement. According to the manufacturer (Dentatus Ltd), the trans-illuminating post technology for restoration compromised fragile roots. Using light-cured composites, it is possible to reinforce the root structure, providing maximum sheer load support.

Although most previous studies applied the load in several angle to the long axis of the tooth (13, 23), we decided to use an angle of 45°, in agreement to studies of El-Khodery et al. (8) and Burgess et al. (17) and load occurring in the lingual area. The speed used for the compression was 1 mm min^{-1}. Higher speed, as of 3 cm min^{-1}, could cause impact (3) instead of compression, which was the purpose of the present research.

In this study, we verified that the root reinforced with zirconium post or composite resin, increased significantly the resistance of the simulated immature dental structure to compression. Immature teeth can suffer recurrent fractures with consequent loss of the dental element. Thus, it is important the use of root reinforcements during the apexification process and after the treatment in order to minimize damages to the tooth. Such reinforcements do not need to be sophisticated using expensive posts systems. According to the present study, the use of composite resin can increase the structural resistance in simulated immature teeth as the zirconium posts system would do.

Conclusion

In the present study, the use of root reinforcements with zirconium fiber post or composite resin significantly increased the structural resistance of the simulated immature teeth, decreasing the risk of fracture.

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