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Effect of intracanal diode laser irradiation on fracture resistance of roots restored with CAD/CAM posts

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Aim: To evaluate the fracture resistance of roots restored with CAD/CAM-fabricated posts, receiving or not intracanal laser treatment, compared with glass fiber posts under mechanical cycling. **Methods:** Twenty-seven endodontically treated, single-rooted teeth were divided into 3 groups: group 1 (control), prefabricated glass fiber posts relined with resin composite; group 2, CAD/CAM-fabricated intraradicular posts using Resin Nano Ceramic (RNC) blocks; and group 3, CAD/CAM-fabricated intraradicular posts using RNC blocks in canals irradiated with a 940-nm diode laser (100 mJ, 300-um optic fiber, coronal-apical and apical-coronal helical movements, speed of 2 mm/second, 4 times each canal). After cementation of the coping, cyclic loading was applied at an angle of 135° to the long axis of the root, with a pulse load of 130 N, frequency of 2.2 Hz, and 150,000 pulses on the crown at a point located 2 mm below the incisal edge on the lingual aspect of the specimen. Every 50,000 cycles, the specimens were evaluated for root fracture occurring below or above the simulated bone crest. Results were analyzed by one-way ANOVA followed by Tukey's test ($p<0.05$). **Results:** Group 1 was the least resistant, while groups 2 and 3 were the most resistant. Group 1 differed significantly from groups 2 and 3 ($p<0.01$), but there was no difference between groups 2 and 3 ($p<0.01$). **Conclusion:** Treatment of the intracanal surface with diode laser had no influence on fracture resistance of roots restored with CAD/CAM-fabricated posts, but a longer cycling time is required to evaluate the real benefits of diode laser irradiation.

Keywords: Lasers. Endodontics. Dentistry. Computer-aided design.

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Introduction

Endodontically treated teeth are at increased risk of fracture due to loss of healthy tooth structure, which may result from inadequate access cavity preparation, carious lesions, and/or extensive restorations[1]. In order to improve crown retention and stress distribution on the remaining tooth structure, the use of intraradicular posts fabricated from different materials is indicated[2].

Metal alloys are the oldest materials, but their high modulus of elasticity (100-200GPa) is much higher than the dentin (18GPa), what can lead to root fracture. In contrast, prefabricated carbon and glass fiber posts have a lower modulus of elasticity-similar to dentin- and are presented in different diameters and tapers. Even when the most adjustable post to the prepared root canal is selected, the film thickness of the luting cement may be higher, which reduces fracture resistance[3]. With the development of the CAD/CAM system, intraradicular posts can replace the intracanal and coronal portions in one piece, thus reducing the resin-cement interface, shortening clinical time, and enhancing adaptation[4].

Recent studies have shown that CAD/CAM-fabricated intraradicular posts increase root fracture resistance, providing an alternative to the use of prefabricated and cast metal posts[5]. An *in vitro* study[6] compared the fracture resistance of flared canals restored with CAD/CAM post- and -core with prefabricated glass fiber and cast gold alloy posts. Radicular fractures occurred in all 3 groups. However, CAD/CAM post-and -core reduced the occurrence fractures in the middle and in apical 1/3 part of root. Fractures in those regions are irreparable and, consequently, catastrophic to root survival[6].

Debonding of posts to the dentin wall is a currently concern. Despite the promising results obtained with CAD/CAM fabricated intraradicular posts regarding to fracture resistance of root canals, there is no protocol for post surface treatment that ensures better adhesion to the dentin. Simple procedures are indicated, such as use of 70% alcohol during cleaning of the posts and use of an universal adhesive. Different surface treatments of CAD/CAM glass fiber posts with 24% hydrogen peroxide and a moisture of silane and ethanol solution did not influence in bond strength values[7,8].

The bonding quality can be influenced by the type of dentin and the presence of smear layer produced during chemomechanical preparation[9,10]. Smear layer can be removed by using suitable chemical substances and high-power lasers[11-16].

Studies testing fracture resistance of roots after dentin pretreatment using diode lasers and luting a CAD/CAM post are scarce, especially using resin nanoceramic CAD/CAM blocks- Lava ™ Ultimate CAD / CAM Restorative, 3M ESPE, USA which have, according to the manufacturer, a modulus of elasticity (12,8GPa) similar to the dentin (18 GPa). In view of this scenario, it seems pertinent to evaluate the fracture resistance of roots restored with CAD/CAM-fabricated intraradicular posts made from Lava™ Ultimate blocks, receiving or not intracanal treatment with high-power diode laser, compared with glass fiber posts relined with resin composite under mechanical cycling.

Materials and Methods

Specimen selection and preparation

Twenty-seven single-rooted human permanent teeth without fractures, cracks, or fissures were obtained by donation from the human tooth bank of APCD São Caetano do Sul, São Paulo, Brazil. The sample size was based on previous studies[6,7] that used 10 samples per group. In our study, 9 specimens were used, as there was a loss of 3 samples in the preparation (considering a significance level of 5%, we had a power of 0.77 to detect differences between groups with specimen rates of 25% and 85%, respectively). The crowns were removed with a carborundum disc, leaving a root length of 14 mm. The root canals were prepared with R25 Reciproc files (VDW, Munich, Germany) and irrigated with 1% sodium hypochlorite (NaOCl), and the cavities were lubricated with a water-soluble lubricating gel (Endo-PTC Leve; Fórmula e Ação, São Paulo, SP, Brazil). After chemomechanical preparation, final irrigation was performed with 10 mL of 1% NaOCl, 10 mL of 17% EDTA-T, and 10 mL of 1% NaOCl. The specimens were obturated with R25 Reciproc gutta-percha cones (VDW, Munich, Germany) and AH Plus sealer (Dentsply, Pennsylvania, USA). The apical 4 mm of gutta-percha were left in the canal, and the remaining 10 mm of the root canal were prepared with a #2 DCR drill of the White Post DCE glass fiber post kit (FGM, Joinville, SC, Brazil), leaving a 10-mm post space.

Randomization of specimens

The teeth were numbered and randomly divided (www. randomizer.com) into 3 experimental groups of 9 teeth each. In group 1 (control), prefabricated glass fiber posts (FGM, Joinville, SC, Brazil) relined with resin composite (Filtek Z350 XT, 3M ESPE, Brazil) were used- G1 GFRC. In group 2, root canals were scanned for fabrication of intraradicular posts with a CAD/CAM system (Cerec inLab MC XL, Sirona Dental Systems, Inc., NY, USA) using Resin Nano Ceramic (RNC) blocks (Lava™ Ultimate CAD/CAM Restorative, 3M ESPE, USA)- G2 CAD. In group 3, root canals were scanned for fabrication of intraradicular posts with a CAD/CAM system (Cerec inLab MC XL, Sirona Dental Systems, Inc., NY, USA) using RNC blocks (Lava™ Ultimate CAD/CAM Restorative, 3M ESPE, USA) and then irradiated with a 940-nm diode laser (Biolase) at 100 mJ, with an optic fiber of 300 um in diameter and helical movements from the coronal to the apical part of the canal and from the apical to the coronal part of the canal at a speed of 2 mm/second. Each canal was irradiated 4 times- G3 CAD/Laser.

Post preparation and cementation

All posts were cleaned with alcohol and dried with air spray. Silane was then applied for 1 minute, followed by spray drying and a thin layer of Single Bond Universal adhesive (3M ESPE, Brazil) was applied during 20 seconds without polymerization. The canals were irrigated with 1% NaOCl and dried with sterile paper points. A thin layer of Single Bond Universal adhesive (3M ESPE, Brazil) was applied, followed by application of RelyX™ Ultimate dual cure resin cement (3M ESPE, Brazil) inside the canal. The prepared post was inserted into the root canal and light-cured for 3 seconds. After excess luting material was removed, a final light curing was performed for an additional 40 seconds.

Mechanical cycling

The #2 drill previously used for post space preparation was inserted into the root canal, and the set (root + drill) was placed in the surveyor so that it was tilted at an angle of 135°. The root was fixed inside an acrylic cylinder (diameter of 12 mm and height of 20 mm) by using a high-viscosity crystalline epoxy resin.

For cycling, ceramic copings were manufactured with a CAD/CAM system (IPS emax CAD, Ivoclar Vivadent). They were cleaned with alcohol and dried with air spray, followed by application of silane (Monobond N, Ivoclar Vivadent, Barueri, SP, Brazil) for 1 minute, followed by spray drying for 1 minute. A thin layer of adhesive was applied without polymerization, and the coping was secured on the already cemented post with dual cure resin cement (RelyX™ Ultimate, 3M ESPE, Brazil).

Load was applied at an angle of 135° to the long axis of the root (figures 1 and 2), with a pulse load of 130 N and frequency of 2.2 Hz, for a total of 150,000 pulses on the crown at a point located 2 mm below the incisal edge on the lingual aspect of the specimen.

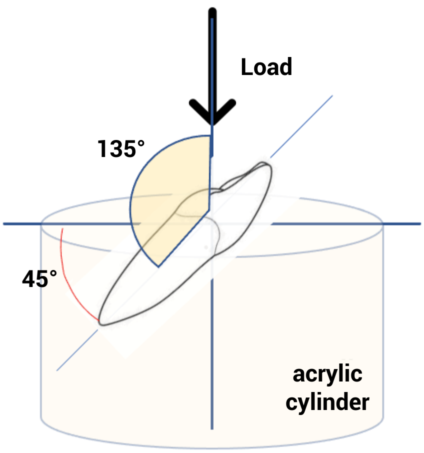

Figure 1. Load was applied at an angle of 135° to the long axis of the root.

Figure 2. Specimen being cycled in the Biocycle-Piopdi cycler (São Carlos, SP, Brazil).

Analysis of specimens

Every 50,000 cycles, the roots were evaluated by a calibrated observer at 4x magnification with prismatic loupes (Zeiss EyeMag Pro S, Carl Zeiss). Fractures that occurred in the cementation during the tests were classified as favorable (above 3 mm, which was the simulated bone crest) and unfavorable (below the simulated bone crest).

The collected data was analyzed by one-way ANOVA followed by Tukey's test ($p<0.05$).

Results

Table 1 shows the total number of cycles until fracture occurred. In group 1 (prefabricated glass fiber posts relined with resin composite), fractures occurred just above the simulated alveolar bone crest (favorable) – figure 3. Figure 4 shows a boxplot of the total number of cycles until fracture occurred per experimental group.

Table 1. total number of cycles until fracture occurred

Root Fracture	G1 FR	G2 CAD	G3 CAD/Laser
1	20000	71434	-
2	17148	-	-
3	17853	-	-
4	24926	-	-
5	39779	-	-
6	54230	-	-
7	-	-	-
8	-	-	-

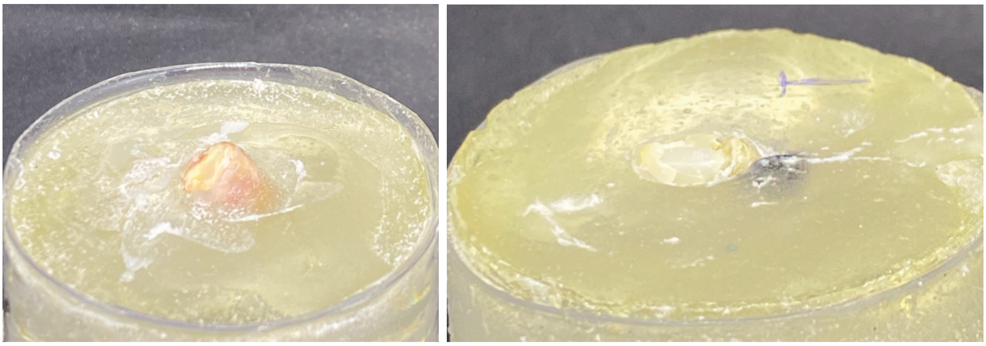

Figure 3. Two specimens above the simulated alveolar bone crest

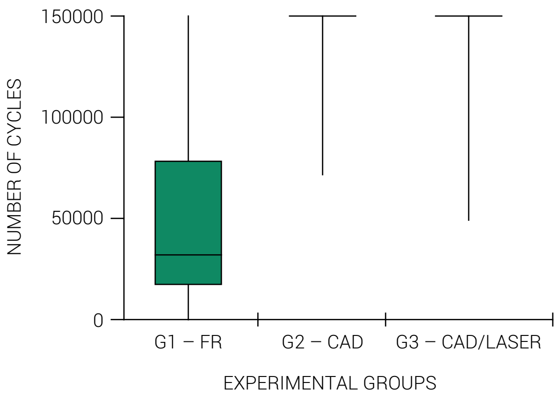

Figure 4. Boxplot of total number of cycles/ fracture. 93 x 67mm (600 x 600 DPI)

Group 1 was the least resistant, while groups 2 (CAD/CAM-fabricated posts) and 3 (CAD/CAM-fabricated posts in laser-irradiated root canals) were the most resistant. One-way analysis of variance revealed statistically significant differences between the groups ($p<0.01$), and Tukey's test showed the following results: significant differences between groups 1 and 2 and between groups 1 and 3 ($p<0.01$), but no difference between groups 2 and 3. Groups 2 and 3 showed virtually no fracture in the parameters analyzed. The specimen survival rate (non-fractured roots) was 25% in group 1 and 87.5% in groups 2 and 3 (Table 2).

Table 2. specimen survival rate

Specimen group	G1 FR	G2 CAD	G3 CAD/Laser
1	20000	71434	150000
2	17148	150000	150000
3	17853	150000	150000
4	24926	150000	48654
5	39779	150000	150000
6	54230	150000	150000
7	150000	150000	150000
8	150000	150000	150000
Survival rate	**25%**	**87,5%**	**87,5%**

The specimens number 1 in group 2 and number 4 in group 3 showed fracture of the coping, thereby adversely affecting the test results.

Discussion

Restoring endodontically treated teeth is challenging due to weakened roots and absence of dental crown or intraradicular dentin[17,18]. Intraradicular posts are commonly indicated to aid in the reconstruction of these elements[19], but even though irreversible root fracture may still occur, leading to tooth loss. Metal intraradicular posts have a high modulus of elasticity, thus placing greater stress on the remaining root and increasing the risk of fracture[20-27]. For this reason, metal posts were not included in this study.

In vitro[23,28-35] and clinical[21,22,36] studies have shown a better performance of prefabricated glass fiber posts when they are relined with resin composite, as this would reduce the amount of cement between the resin and intracanal wall. This justifies the relining of specimens in group 1. However, relining the prefabricated posts with resin composite did not ensure fracture resistance in this group compared to CAD/CAM groups (2 and 3). The rate of non-fractured roots (survival rate) was only 25%. In glass fiber posts, fracture occurs by shear stress when forces are loading at an angle of 45° to the long axis of the tooth[31].

For a long time, prefabricated glass fiber posts have been the posts of choice to restore endodontically treated teeth. However, with the development of the CAD/CAM system, it is possible to fabricate posts that better adapt to the intraradicular canal. These posts are indicated mainly for use in oval or wide canals, in addition to providing a better aesthetic outcome, increased retention, and lower film thickness of the luting cement[6,37]. It is imperative to highlight the increased fracture resistance that the CAD/CAM system provides to the root[6,38], which supports the choice of this system in the present study. Moreover, the specimen survival rate in groups 2 and 3 was higher than that in group 1, i.e., there was less root fracture – except for the fracture of copings in specimens number 1 and 4 in groups 2 and 3, respectively – which is consistent with the results reported in other studies[5,6,39].

Several materials can be used in the CAD/CAM system. In the present study, Lava™ Ultimate RNC was chosen because of its good performance in root fracture resistance tests compared with other materials, according to the results reported by Spina et al.[37]. In addition, according to the manufacturer (3M ESPE, Brazil), this material has a nanoceramic content of 80%, thus providing the benefits of both resin (modulus of elasticity similar to that of dentin) and ceramic (color stability and hardness).

Bond strength is another extremely important factor when investigating intraradicular posts, as well as a determinant of treatment success[40-45]. Dentin-post-cement interactions are influenced by some factors such as integrity of the root canal wall, polymerization of the resin cement, and contamination of the root canal, all of which can increase the risk of root fracture[42]. In the present study, before cementation, the canal walls were examined under an operating microscope and, if impurities were observed in the intracanal wall, they were removed with an XP Endo Finisher rotary file (FKG, Switzerland) aiming to improve cement bonding to the root canal wall.

The significantly superior results obtained with CAD/CAM-fabricated posts (groups 2 and 3) over prefabricated glass fiber posts (group 1) were expected by the authors of the present study based on the existing literature. However, a question arose as to whether diode laser treatment of root canals would have a beneficial effect on post bonding to the canal walls and, consequently, on root fracture resistance, since there is a vast literature on the action of diode laser on dentin permeability, smear layer removal, and structural changes in the dentin[11,46-49], factors closely related to bond strength. This justifies the inclusion of group 3.

Studies with intraradicular surfaces irradiated with a 980-nm diode laser[50] and Er:YAG, Er,Cr:YSGG[51] presented an improvement in bond strength of glass fiber posts compared to non-irradiated groups. These findings are in agreement with this study, when group 3 is compared to group 1. However, because bond strength of groups 2 and 3 did not differ significantly, authors can not state that diode laser treatment improved fracture resistance.

The present study performed 150,000 cycles. For more robust results, it will be necessary to manufacture new copings and to continue mechanical cyclic loading until all specimens have fractured, simulating longer time in the mouth, according to other studies[37,39]. Clinical studies are important to validate these *in vitro* findings. In addition, studies applying different lasers and parameters are required.

Based on the present results, it can be concluded that CAD/CAM-fabricated intraradicular posts made from Lava™ Ultimate blocks provided greater fracture resistance of roots than prefabricated glass fiber posts relined with resin composite. Treatment of the intracanal surface with diode laser had no influence on fracture resistance of roots restored with CAD/CAM-fabricated posts, but a longer cycling time is required to evaluate the real benefits of diode laser irradiation.

Author Disclosure Statement

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Conflict of Interest: No competing financial interests exist.

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