Push - out Bond Strengths of Three Different Endodontic Sealers

A comparative study

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The bond strength of the root canal sealers to dentin and core material seems to be a very important property for maintaining the integrity and the seal of root canal filling. This in vitro study aimed to evaluate and compare the bond strength of three different root canal sealers. Forty five extracted single-root human teeth were prepared using ProTaper system. Teeth were divided into three groups (n=15) for obturation using AH Plus, RealSeal and a new, experimental endodontic sealer containing hydroxyapatite. Each tooth was obturated using warm vertical condensation technique in the apical third and gutta-percha injection in the middle and coronal thirds of the root canal. All teeth were sectioned transversally at the apical and middle thirds into 1 mm thick discs. Push-out tests were performed using a universal mechanical testing machine (Lloyd Instruments – LR5k plus). The maximum load at failure was recorded and divided by the area to obtain the bond strength in MPa. Using a stereomicroscope (STEMI 2000 C Zeiss, Jena, Germany), at a magnification of 20x, the interface where the obturation failure occurred was identified. Statistical analysis was performed and the result showed non significant differences between the three endodontic sealers at each level obturation. Also, the stereomicroscopic analysis showed a good adhesion to dentin for all sealers. The experimental sealer adhesion is comparable to that of the two consecrated materials.

Keywords: push-out test, bond strength, endodontic sealer, root canal obturation

Sealer should demonstrate adhesive properties to dentin, decreasing chance of endodontic treatment failure, increased adhesive properties to dentin may lead to greater strength of restored tooth, which may provide greater resistance to tooth fracture and clinical longevity of endodontic treated tooth [1].

Epoxy resin-type sealers have been used for many years, showing higher bond strength to dentine than zinc oxide eugenol types, calcium hydroxide-based sealer and a glass–ionomer sealer [2].

Endodontic filling using urethane dimethacrylate resin is claimed to create a tight seal with the dentinal tubules within the root canal system. In essence, it produces a "monoblock" effect, where the core material, sealer and dentinal tubules become a single solid structure [3]. Shipper et al. [4] suggested that this monoblock would be highly desirable to provide a thorough seal of the root canal system, as it would be able to minimize coronal leakage in case of loss or fracture of the temporary coronal restoration.

Gutta-percha associated with sealer is commonly used with various techniques to enable the dentist to accurately and thoroughly obturate root canal system**.**

Adhesion of sealers to dentin is a required property for root canal sealers. Although standard organization does not provide any data concerning the minimal required bond strength for endodontic sealers, it has been subject of several studies [5-10].

It has been suggested that the ability of root canal sealers to adhere to core material and to dentin may result in superior sealing ability, which could reduce coronal and apical leakage [7].

Differences in the adhesive properties of sealers to dentin may be expected for several reasons, including differences of root dentin between specimens, or even in different sites of the same root [2, 6].

Thus, the present study was intended to assess the bond strength to root canal walls for three endodontic sealers: an epoxy resin – AH Plus (Dentsply De Trey GmbH, Konstanz, Germany), an urethane dimethacrylate resin – RealSeal (SybronEndo, Orange, CA, USA) and an experimental hydroxyapatite based sealer designed for this study, all of these in association with gutta-percha.

Experimental part

Preparation of the sample

Forty five monoradicular teeth were included in the present study. The teeth were extracted for orthodontic or periodontal reasons 4 weeks before starting this experiment. For the batch uniformity, there were performed digital x-rays in two different angles. The teeth that had internal root resorption, calcifications, previous endodontic treatments or teeth that have been identified with more than one canal per root, were removed from the study.

The teeth were coronary sectioned in order to obtain a 16 mm working length, identical in the whole studied group.

The working length was determined visually by introducing a K-file instrument into the root canal (ISO MM® diameter 10/100 mm), until the tip was visible at the apex. The working length was determined by withdrawing the instrument for 0.5 mm.

Teeth preparation

<u>Mechanical-antiseptic preparation of the root canals</u>

The teeth were prepared at working length using ProTaper® system (Dentsply Maillefer) and X - SmartTM endodontic micromotor Motor® (Dentsply, UK) in

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continuous rotation until F2 instrument at the speed of 250 rpm (revolutions per minute), according to the manufacturer's instructions.

The mechanical and antiseptic treatment involved the use of chelating gel MM EDTA® (Micromega, France) on each of the endodontic preparation instrument and continuous irrigation with sodium hypochlorite concentration of 2.5 % (5 mL per sample). At the end of the preparation, the root canal was irrigated with 1 mL EDTA 8% concentration, maintained for 3 min in order to remove the smear layer. The canals were dried using paper points adjusted at the working length.

The root canals obturation

The sample of 45 teeth was randomly divided into three groups (n = 15). Each tooth of these groups was endodontically obturated using gutta-percha in combination with an experimental hydroxyapatite based sealer and two consecrated sealers - RealSeal (USA) and AH Plus (Germany). The obturation technique used was warm vertical condensation technique in apical third and injection of gutta-percha in the coronal two-thirds.

To allow the complete setting of the sealers, the teeth were preserved in a solution of sodium hypochlorite concentration of 2.5%, 100 % humidity and a temperature of 37 ° C for 7 days. After the complete setting of the sealers, the samples were placed in distilled water for 10 min, rinsed with absolute ethanol for 15 min and then placed in an oven at a constant temperature of 37° C for 24 h in order to dry them.

The samples, properly dried, were placed in resin blocks and left for 24 h to complete the setting reaction of the resin.

The push-out test

The teeth included in the resin blocks were sectioned using the microtome (Microtom Buehler-IsoMet 1000) in slices of 1 mm, starting from apical to coronal. There were selected those teeth slices that have not damages after cutting.

A constant force was applied, by means of a cylinder-piston of 0.70 mm thick attached to a universal mechanical testing machine (Lloyd Instruments – LR5k plus), to each slice of tooth. On the surface of the filler material, a constant load of 0.5 mm/min was maintained until failure, causing so shear forces at the interface sealer/dentin and at the interface sealer/core material. Failure forces were recorded for each section of the tooth.

The retention strength S (MPa) of the "monoblock system" of the tested tooth slice was calculated by dividing the release force F (N) at the side surface A (mm^2) of the obturation segment: $S=F/A$

The root canal is considered as having a cone shape and the tooth slices as having a truncated cone shape; each root canal section diameter was measured on each of the two sides of the slices to calculate large radius (R) and small radius (r). The side area of the root canal section, in the form of a truncated cone, was calculated by the formula: $A = 2\pi G (R + r)$, where G is the generator of the truncated cone.

Each tooth slice was numbered and examined on both sides, before and after the push-out test under the stereomicroscope (STEMI 2000 C Zeiss, Jena, Germany), at a magnification of 20x.

The bond strength values for all sealers were analyzed and compared using ANOVA statistical test and SPSS Statistic Software.

Results and disscutions

The mean bond strenght in the apical third was the lowest for AH Plus (0.6524±0.43) and the highest for the experimental hydroxyapatite sealer (1.3096±0.01), but the diferences were not statistically relevant (p=0.09). RealSeal recorded a lower mean bond strenght (0.7177±0.55) in the apical third comparing to the experimental hydroxyapatite based material (p=0.1).

In the middle third the experimental hydroxyapatite sealer recorded the lowest value for the mean bond strenght (0.8294±0.18) and RealSeal the highest value (1.4367±1.05), but the results were not statistically validated (p=0.3). AH Plus obtained lower values (1.0062±0.90) for the mean bond strenght than Reals Seal in the middle third, but higher than the experimental hydroxyapatite sealer (p=0.7) (fig. 1).

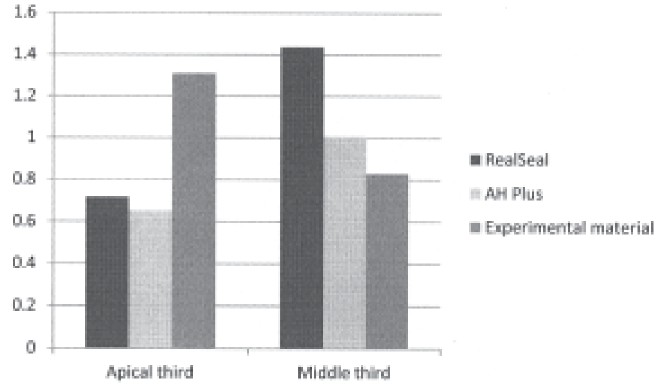

Fig. 1. Comparative distribution of the mean values of the bond strengths for the three studied sealers

Regarding the interface where the obturation failure occurred - interface sealer / dentin or interface sealer / gutta-percha, we observed a good adhesion to dentin for all the materials.

So, for the RealSeal, 80 % of the samples failed at the interface of the sealer / gutta-percha or inside of gutta-percha cone. For AH Plus, 72.5 % of the samples had similar failures and the experimental sealer, 77.5 %. On average, 40% of these failures were inside the core material (gutta-percha) or combined failures (fig. 2-4).

The bond strength of root canal sealers to dentin is important for maintaining the integrity of the seal in root canal filling in both static and dynamic situations [7]. In a static situation, it should eliminate any space that allowed the percolation of fluids between the filling and the wall; in

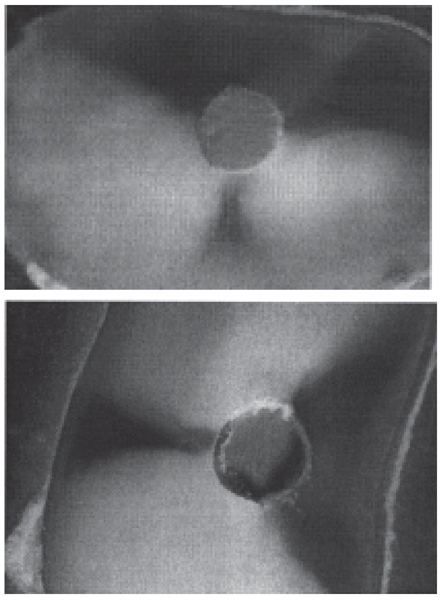

Fig. 2. Gutta-percha/sealer interface failure (experimental sealer)

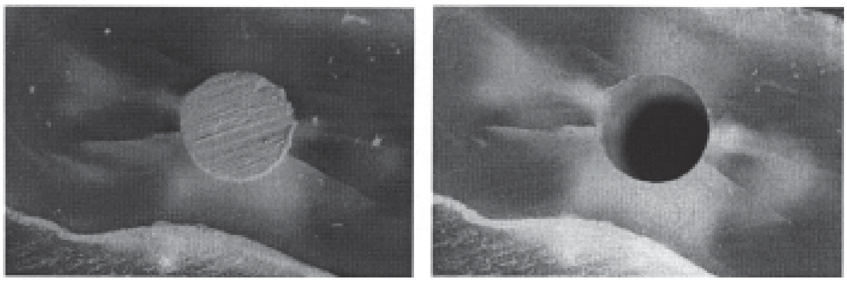

Fig. 3. Dentin/sealer interface failure (experimental sealer)

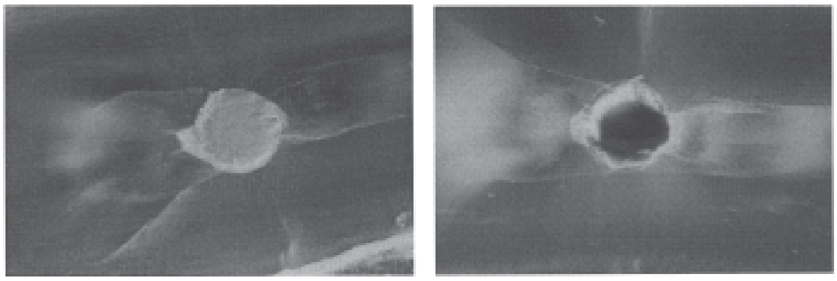

Fig. 4. Core material failure – gutta-percha (experimental sealer)

a dynamic situation, it was needed to resist dislodgement of the filling during subsequent manipulation [11].

During chemo-mechanical preparation, a layer of debris, the smear layer, is formed. Current theories of dentine bonding mechanisms involve either chemical modification of the smear layer and bonding directly to it, or removal of the smear layer and bonding to subjacent tooth structures [12]. Some studies have shown that removal of the smear layer enhances the adhesion of sealers to the root canal wall [7, 13].

Bond-strength testing had become a popular method for determining the effectiveness of adhesion between endodontic materials and tooth structure. There were many methods for measuring the adhesion of endodontic root canal sealers, but none had yet been widely accepted [14].

In this study, the push-out test method was used to test the dentin bond strengths of different root canal sealers; the model had been shown to be effective and reproducible. Another advantage of this method is that it allowed root canal sealers to be evaluated even when bond strengths are low.

In our study, at the apical third, the experimental sealer had the highest mean bond strength. In descending order RealSeal and AH Plus followed. In the middle third, however, the experimental sealer had the lowest mean bond strength and RealSeal the highest bond strength. Regarding AH Plus and RealSeal, the results are consistent with the results obtained by Ungor et al. [15].

The heat generated by the injected gutta-percha in the middle third could explain the variations that occurred in the case of the experimental sealer. Lawson et al. [16] concluded that the evaporation of the liquid resin component of the sealer by heat generated during obturation technique could result in a highly viscous sealer that had a limited flow capacity into the patent dentinal tubules and lower bond strength; also the rate of polymerization may be accelerated by heat and increase shrinkage and decrease bond strength.

Another explanation for the lower bond strengths at sealer/dentin interface detected in the groups containing a methacrylate resin-based sealer is the effect of cavity configuration factors (C.Factor:the ratio bonded to unbonded surface). C-Factor is found to be extremely high in long, narrow root canals. Virtually every dentin wall had an opposing wall that produces a very limited unbounded surface area to provide relief from the stresses created by polymerization shrinkage. It is likely the bond between sealer core and sealer dentin is not adequate enough to resist this debilitating stress that develops during polymerization resulting in gap formation [17]. However, the differences between the values of bond strength may occur due to variable thickness of the layer of sealer.

Resin-based sealers penetrate the dentinal tubules for a considerable length [4, 18], and if the resin filler particles are bigger than the diameter of the tube, only the matrix penetrate these tubules and the particles form an uncured layer in contact with dentin. Thus, an insufficiently thick layer of sealer may result in poor adhesion [19].

Numerous investigations have shown that the resin-based sealer AH Plus has higher bond strength than most other sealers [4, 7, 20]. In the present study, the AH Plus sealer and gutta-percha core combination also showed good adhesion properties. This adhesion could be explained by the reduced shrinkage, dimensional stability or inherent volumetric expansion [18].

Conclusions

Adhesive strength is only one aspect of the quality of root canal sealing. Further investigation of other features of root canal sealers is required. In most cases, the results of laboratory experimental studies cannot be directly transposed to the clinical situation. However, they do provide reproducible and reliable means for comparing and testing new and prospective sealers, and for establishing international standards. Within the limitations of our study, we can say that our experimental sealer adhesion is comparable to that of the two consecrated materials.

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Manuscript received: 1.04.2015