Depth of cure of bulk-fill and flowable resin in contact with mineral trioxide aggregate plugs in ex vivo immature teeth

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Abstract

Introduction: Tooth development may be interrupted when the pulp becomes necrotic because of caries, trauma, or anatomical alterations such as dens evaginatus. Objective: To determine the depth of cure and hardness of an injected bulk-fill resin (Sonic Fill™) compared with a flowable resin (Revolution™) in teeth with incomplete apex formation. Material and Methods: Forty recently extracted uniradicular teeth were assigned for the study; 3 mm of the apex was cut to standardize all teeth to 13 mm, then the root canals were instrumented to a size 1.10 mm by using Peeso drills. A 3-mm mineral trioxide aggregate (MTA) plug was placed in the apical third. After etching the root canal walls, an intracanal adhesive system was placed and cured. Then, Sonic Fill™ was injected into the remainder of the root canal of 20 specimens randomly selected and a flowable composite resin (Revolution™) was placed in the others. All specimens were placed in a rectangular, acrylic base and sectioned along the long axis of the tooth. The depth of cure and hardness of the composite resin were evaluated using the Vickers micro-hardness test and compared with Student T test for independent groups.


Conclusions: Specimens in the SonicFill™ group showed significantly higher Vickers microhardness than those in the flowable resin group, making the former more suitable for strengthening teeth with immature apexes.

Keywords: Bulk resins, dental fractures, immature apexes, intraradicular post, sonicfill

Introduction

Tooth development may be interrupted when the pulp becomes necrotic because of caries, trauma, or anatomical alterations such as dens evaginatus [1]. As a result, it has been reported that failure of an immature tooth occurs in about 30% of the cases due to the thin walls in all thirds of the root, especially the buccocervical third, which is essential for proper restoration ability [2, 3, 4]. Such teeth cannot be cleaned, shaped, or filled using conventional treatment methods [5].

One treatment method is revascularization, consisting of disinfecting and then creating an ingrowth of scaffolding of blood vessels along the root canal walls, which would ideally result in hard tissue deposition; this has been recommended as the newest treatment method [6]. In revascularized teeth, the root canal is usually not reinforced in the cervical third, which can result in a fracture due to the external forces concentrating in the crestal bone area [7, 8]. Apexification has also been recommended as a treatment method that involves disinfecting the root canal and placing Mineral Trioxide Aggregate (A powder consisting of fine hydrophilic particles, the principal components of which are reportedly tricalcium silicate, tricalcium aluminate, tricalcium oxide, and silicate oxide) in the apical third offering a barrier at the end of the root canal (apical plug) to allow for apical closure [9, 10, 11, 12]. This is a technique that has been shown to be highly successful with follow-ups of up to 10 years [13].
After root canal treatment, immature teeth are usually restored using composite resins, with a core for a full crown or prefabricated fiber posts and core as retention for a crown. Fiberglass posts have been used because they have an elastic modulus similar to dentin, thus distributing stress forces throughout the post cement dentin interface without concentrating them in a specific area. However, prefabricated posts also have some disadvantages. First, accurate placement is a time-consuming procedure. Moreover, incomplete adaptation to the root canal walls can result in areas with a thick cement volume as well as formation of bubbles and voids. For this reason, both fractures and post dislodgement have been reported.

Bulk-fill resins are composite resins with the ability to be thoroughly cured in bulk, while problems such as the implementations of voids between consecutive layers and possible contamination between them are avoided. SonicFill (SF; Kavo-Kerr, Orange, CA, USA) is a bulk-fill resin that undergoes liquefaction in a hand piece activated by sonic vibration, allowing the composite to flow freely during placement.

A bulk resin is easily injected into the root canal and, if properly polymerized, can better adapt to the root canal anatomy and should seal and reinforce the root better than a fiber post. However, the root canal presents difficult conditions for light curing because of the lack of light penetration as well as the C-factor, which limits proper intracanal polymerization in other types of resins. On the other hand, if SF could achieve a proper penetration and light curing in a prepared post space, its microhardness would facilitate restoration of the immature roots and considering that flowable resins may be an option due to their ease of penetration and fluidity it could be a substitute. Therefore, the purpose of the present study was to compare both the penetration and depth of cure of SF and the conventional, flowable resin, Revolution, after being injected into a root canal post space of immature teeth when in contact with Mineral Trioxide Aggregate (MTA).

Materials and Methods
This study was approved by Ethics committee (2001-2019).

Sample selection
Forty recently extracted uniradicular teeth were assigned for this study. Roots that were fractured or fissured were excluded. All the teeth were checked using a stereomicroscope (Olympus BX43; Olympus Co., Tokyo, Japan) under 20 magnification to determine whether there were any root fractures or cracks. The roots were disinfected with 1% NaOCl and placed in physiological saline solution to prevent dehydration until used.

Access cavity preparation and root canal preparation
Coronal access was gained with a size 4 round bur (Brasseler, Savannah, GA, USA) under copious water irrigation. A size 15K file (Kavo-Kerr, orange, CA, USA) was used until the file tip was visible at the foramen under magnification, then the canals were flared with TFA ML1-3 (Kavo-Kerr) and shaped to working length. 3 mL of 5% NaOCl (Clorox, Pleasanton, CA, USA) were used to irrigate the canal after each instrument. The root canals were further flared to a size 1.10 by using a Peeso drill (Densply-Sirona, York, PA, USA).

A final irrigation with 17% EDTA (REDTA Roth International, Chicago, IL, USA) was used for 1 min, then the canals were dried with sterile paper points (Kavo-Kerr). All roots were standardized to 13 mm in length by cutting 3 mm off the apex using a diamond saw, then 3 mm of Mineral Trioxide Aggregate, (MTA, ProRoot; Densply-Sirona) was packed into the apical third using MTA pluggers and an operating microscope. Radiographs were obtained to make sure there were no voids in the apical MTA plug, and the material was allowed to set for 24 h.

After setting of the MTA, all teeth were isolated using a rubber dam and Block-Out resin (Ultradent Products, South Jordan, UT, USA), the post space was then cleaned and etched with phosphoric acid 37% for 20 s, and the canals were irrigated with 5 mL of distilled water and dried with sterile paper points.

Filling of the root canal

Group 1 (SF; n = 20)
One drop of Optibond Solo Plus (Kavo-Kerr) bonding agent was introduced into the prepared canal with a microbrush and agitated against the canal walls. The remnants were removed with sterile paper points and the adhesive photopolymerized for 5 s with a Demi Plus (Kavo-Kerr) using a wavelength of 470 nm and intensity of 1300 mW/cm².

Once the dental unit was determined to have an atmospheric pressure of 70 psi (483 kPa), the composite capsule was attached to the hand piece and the dispensing rate/speed set at 3. The tip of the SF (A3) was placed 0.5 mm above the deepest part of the preparation to avoid air entrapment and ensure adequate penetration of the composite material. Filling of the root canal was performed in two increments of 5 mm each that were cured separately.

Once the first increment was placed and polymerized for 20 s, a second increment was similarly placed and polymerized, followed by a final polymerization of 20 s (Figure 1).

Group 2 (Revolution; n = 20)
In the remaining 20 roots, Optibond Solo Plus (Kavo-Kerr) adhesive was placed and photopolymerized in the same way described in group 1. Revolution resin (Kavo-Kerr) was placed in two increments of 5 mm each, and each increment was polymerized for 20 s. All specimens were stored for 24 h at 37 °C and 100% humidity. All specimens were fixed in 4 rectangular 20 X 4.5-cm plastic bases with acrylic and allowed to harden at room temperature for 24 h. Afterwards, they were sectioned from the occluso-cervical dimension with a sectioning machine (Gillings-Hamco, Rochester, NY) with abundant cold water to avoid overheating the resin (Figure 2). The cut surfaces were polished with 1200-grit abrasive paper using abundant cold water for 60 s (Figure 3).

Hardness values were registered with a durometer (Nanovea PB1000, Orange, CA) in cervico-apical direction in increments of 1 mm from the top of the irradiated surface (Figure 4). A load of 300 g and a dwell time of 15 s with a Rockwell C tip indenter (Rockwell Collins, Salt Lake City, UT, USA) was applied to each specimen until the values reached 80% of those obtained at 1 mm. Each mark left by the indenter in the resin was analyzed with a profilometer (Nex View 3D Optical Surface Profiler, Zygo Corp, Middlefield, CT, USA) (Figure 5).
Fig 1: Radiographs obtained to make sure there were no voids in the apical MTA plug and SF

Fig 2: Specimens sectioned from the occluso-cervical dimension with a sectioning machine (Gillings-Hamco, Rochester, NY)

Fig 3: Longitudinal section through the root showing Sonic Fill resin injected and MTA apical plug

Fig 4: Hardness values registered with a durometer (Nanovea PB1000, Orange, CA)

Fig 5: Mark left by the indenter in the resin analyzed with a profilometer (Nex View 3D Optical Surface Profiler, Zygo Corp, Middlefield, CT, USA)

Depth of Cure Calculation
An average of the values from the 40 specimens was obtained and the data was calculated in micro-hardness numbers, using the Vickers formula $HV = P/As$, where $P$ is the test load and $As$ is the surface area of the indentation used.

The microhardness values were averaged for each specimen at each depth to obtain a single value (Tables 1 and 2). Once all the hardness measurements were obtained, the distance from the upper layer of the resin to where 80% hardness was achieved was calculated.
Table 1: Conversion values in Vickers - Sonic Fill (mm-millimeter; mm²- square millimeter; HV- Vickers hardness)

<table>
<thead>
<tr>
<th>Specimen (mm)</th>
<th>Depth (mm)</th>
<th>Diameter (Microns)</th>
<th>Radio (mm)</th>
<th>Area (mm²)</th>
<th>HV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.002</td>
<td>82</td>
<td>0.041</td>
<td>0.0105</td>
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<td>2</td>
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<tr>
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<tr>
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Table 2: Conversion values in Vickers – Revolution (mm-millimeter; mm²- square millimeter; HV- Vickers)

<table>
<thead>
<tr>
<th>Specimen (mm)</th>
<th>Depth (mm)</th>
<th>Diameter (Microns)</th>
<th>Radio (mm)</th>
<th>Area (mm²)</th>
<th>HV</th>
</tr>
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Statistical Analysis
Data from both groups were compared with Student t-test analysis with significant differences. Software SPSS v. 25 (IBM, Endicott, Nueva York, USA).

Result
In SF samples, 80% of the first mm was reached after 3 mm of the placement of the second resin increment and 8 mm for the first increment of resin placed. In the case of Revolution™, 80% of the first mm was reached before the 3 mm placement of the second increment of the resin.

Specimens in the SF group showed significantly (p = 1.6 × 10⁻⁶) higher Vickers micro-hardness (24.03±4.09 Kp) I.C.95% [20.88-27.19] than those in the Revolution™ composite group (11.28±3.19 Kp) I.C.95% [8.82-13.72] (Figure 6).

Discussion
The elasticity modulus defined as the stress radius that corresponds to the deformation of a material under load is relevant for research applications. The elastic modulus of composite resin is similar to dentin. For this reason, the material can distribute applied loads by reducing stress concentrations that would make it suitable to restore immature teeth with open apexes [19].

A method frequently used to measure the depth of curing of composite materials is the one described in ISO standard 4049. It claims the quantification of data once the non-cured resin has been discarded from the sample and by dividing the height of the cured material by two; however, this method does not take into account curing by irradiation. On the other hand, the micro hardness Vickers test addresses this limitation allowing the measurement of post light cure and hence can provide variable results [20].

Fluid composite resin materials of low viscosity were manufactured with the same size of particles of conventional resins but reducing the size of particles of the fillers and hence reducing the viscosity of the composite [21]. Fluid composite resin can be used as a liner, fissure sealant, and to restore tunnel form cavities or preparations; however, the lower mechanical properties compared with those of conventional resins limits their use in high-stress restorations [22, 23]. For this reason, they have been replaced by bulk-fill composite resins that can be injected up to 4 mm or more without adverse effects on polymerization shrinkage, adaptation, or degree of conversion. Also, shrinkage is reduced when compared to conventional resins, and hence gaps are also reduced [24, 25]. Some studies have shown that polymerization continues during more than 24 h after light application [26, 27]. The depth of bulk-fill composite-resin polymerization has been improved with the increase in translucency [28] in the size of the filler, and, by improving the refractive index between filler and resin matrix. This last mechanism benefits from the improvement in the efficacy of the photo-initiator [29].

In the case of SF, bis-GMA was replaced by bis-EMA (with lower viscosity), along with siloxane-methacrylate (a flexible copolymer (SIMA) that may increase molecular reactivity of the crosslinking monomers). Sonic vibration within the hand piece may also reduce viscosity by increasing the mobility of the monomer. SF polymerizes with light and absorbs the curing light better than conventional resin [16, 30].
The results of this study show that the injection of bulk-fill resins may be an alternative to restoring immature teeth in contact with bio-ceramic/silicate cement plugs. At the same time, this technique would result in a mono-block from the intracanal post space to the core or coronal restoration by reducing the number of interfaces while providing a better adaptation than posts to oval root canal anatomies and reducing procedural time.

Conclusion
Under the limitations of this in vitro study, specimens in the SF group showed significantly higher Vickers micro-hardness once injected intracanal than those in the flow able resin composite group, thus making it suitable for reinforcing and restoring immature teeth with open apexes.

References