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Eduardo Carbajal
Department of Endodontics, UIC, Ciudad de México, México

Jorge Vera
Department of Endodontics, University of Missouri Kansas City/Universidad de Tlaxcala-Mexico

Ana Arias
Department of Conservative Dentistry, Complutense University, Madrid, Spain

Marino Vazquez
Department of Endodontic, University of Tlaxcala, Tlaxcala, México

Rosendo Carrasco
Benemérita Universidad Autónoma de Puebla, Puebla, México

Cesar Ramos
Department of Endodontics, UIC, Ciudad de México, México

Corresponding Author:
Eduardo Carbajal
Department of Endodontics, UIC, Ciudad de México, México

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

Eduardo Carbajal, Jorge Vera, Ana Arias, Marino Vazquez, Rosendo Carrasco and Cesar Ramos

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Abstract
Introducción: 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.
Result: Specimens in the SF group showed significantly ($p = 1.6 \times 10^{-6}$) 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].
Conclusions: Specimens in the SonicFill™ group showed significantly higher Vickers microhardness than those in the flow able 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 [14]. Fiberglass posts have been used because they have an elastic modulus similar to dentin, thus distributing stress forces throughout the post cement dentin interphase without concentrating them in a specific area [15]. 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 dislodgment have been reported. [16].

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 [17].

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 [18]. 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 x20 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 pre-paration

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/cm^2.

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 (Gillngs-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).

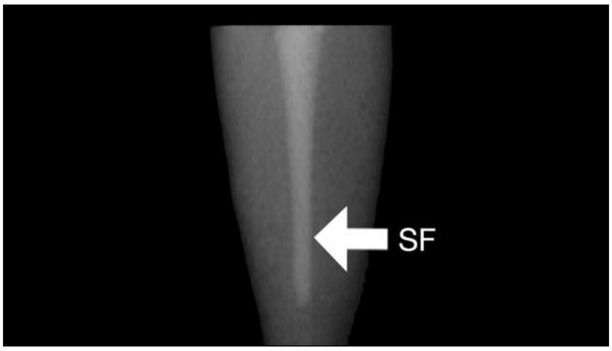

Fig 1: Radiographs obtained to make sure there were no voids in the apical MTA plug and SF

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

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

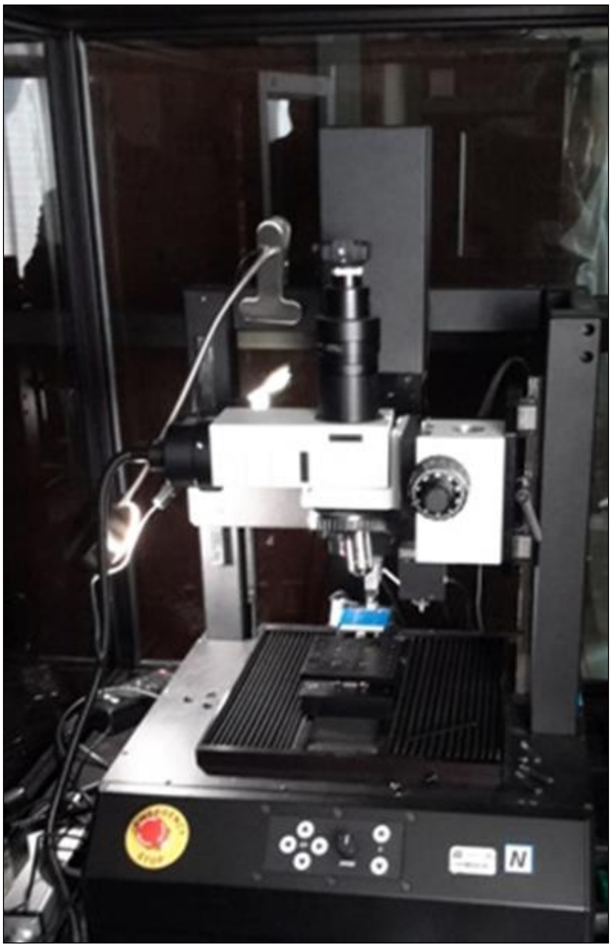

Fig 4: Hardness values registered with a durometer (Nanovea PB1000, Orange, CA)

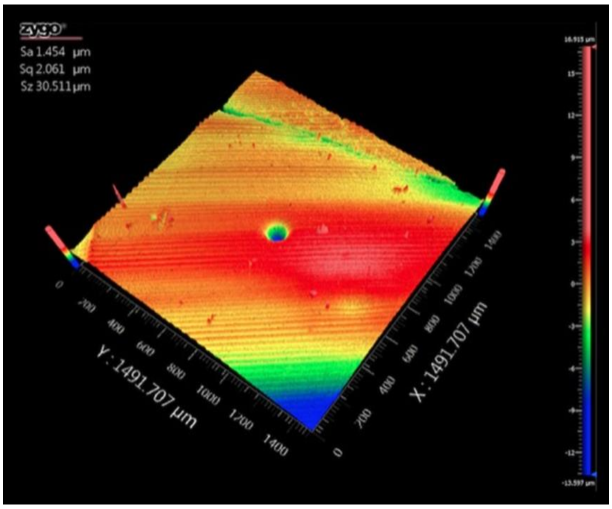

Fig 5: Mark left by the indenter in the resin analyzed with a profilometer (Nex View 3D Optical Surface Profiler, Zygo Corp, Middlefield, CT, USA)

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; mm^2- square millimeter; HV- Vickers hardness)

Specimen (mm)	Depth (mm)	Diameter (Microns)	Radio (mm)	Area (mm^2)	HV
1	0.002	82	0.041	0.0105	28.4
2	0.0022	83	0.0415	0.0108	27.7
3	0.0023	90	0.045	0.0127	23.6
4	0.0024	92	0.046	0.0133	22.5
5	0.0021	84	0.042	0.0110	27.1
6	0.0022	87	0.0435	0.0118	25.2
7	0.0023	89	0.0445	0.0124	24.1
8	0.0025	91	0.0455	0.0130	23.0
9	0.0034	114	0.057	0.0204	14.7

Table 2: Conversion values in Vickers – Revolution (mm-millimeter; mm^2- square millimeter; HV- Vickers)

Specimen (mm)	Depth (mm)	Diameter (Microns)	Radio (mm)	Area (mm^2)	HV
1	0.0038	104	0.052	0.0170	17.6
2	0.0066	113	0.0565	0.020	14.9
3	0.0081	145	0.0725	0.033	9.1
4	0.009	139	0.0695	0.030	9.8
5	0.0075	126	0.063	0.025	12.0
6	0.0055	127	0.0635	0.025	11.8
7	0.0075	140	0.07	0.030	9.7
8	0.0087	148	0.074	0.034	8.7
9	0.0095	155	0.0775	0.037	7.9

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 ($p = 1.6 \times 10^{-6}$) 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).

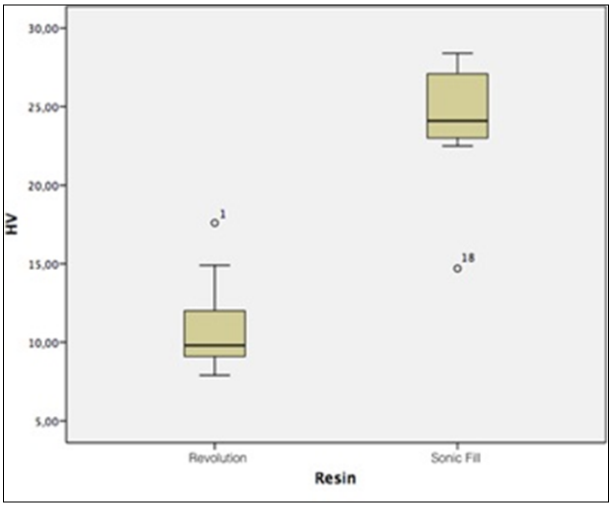

Fig 6: Specimens in the SF group showed significantly ($p = 1.6 \times 10^{-6}$) higher Vickers microhardness (24.03 ± 4.09 *Kp*) I.C.95% [20.88- 27.19] than those in the Revolution™ composite group

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

1. Silujjai J, Linsuwanont P. Treatment Outcomes of Apexification or Revascularization in Nonvital Immature Permanent Teeth: A Retrospective Study. J Endod. 2017 Feb;43(2):238-245.
2. Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha. A retrospective clinical study. Endod Dent Traumatol. 1992 Apr;8(2):45-55.
3. Kattebzabeh N, Dalton B, Trope M. Strengthening immature teeth during and after apexification. J Endod. 1998 Apr;24(4):256-259.
4. Talati A, Disfani R, Afshar A, Akbar F. Finite element evaluation of stress distribution in mature and immature teeth. Iran Endo J Summer. 2007;2(2):475-483.
5. Mahmoud T, Turman M. Revitalization of tooth with necrotic pulp and open apex by Using Platelet- rich plama: A case Report. J Endod. 2011 Feb;37(2):265-268.
6. Nygard-ϕstby B. The role of the blood clot in endodontic therapy: An experimental histologic study. Acta Odont Scand. 1961 Dec;19:324-353.
7. Nicoloso G, Pötter I, Rocha R, Montagner F, Casagrande L. A comparative evaluation of endodontic treatments for immature necrotic permanent teeth based on clinical and radiographic outcomes: A systematic review and meta-analysis. Int J Paediatr Dent. 2017 May;27(3):217-227.
8. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: A systematic review of literature- part I. Composition and micro- and macrostructure alterations. Quintessence Int. 2007 Oct;38(9):733-743.
9. Diogenes A, Ruparel NB, Shiloah Y, Hargreaves K. Regenerative endodontics: A way forward. J Am Dent Assoc. 2016 May;147(5):372-380.
10. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review-part III: Clinical applications, drawbacks, and mechanism of action. J Endod. 2010 Mar;36(3):400-413.
11. Bonte E, Beslot A, Boiukpessi T, Lasfargues J. MTA versus Ca(OH)2 in apexification of non-vital immature permanent teeth: A randomized clinical trial comparison. Clin Oral Investig. 2015 Jul;19(6):1381-1388.
12. Camilleri J, Montesin F, Brady K, Sweeney R, Curtis R, Pitt T. The constitution of mineral trioxide Aggregate. Dent Mater. 2005 Apr;21(4):297-303.
13. Ree M, Schwartz R. Long-term Success of Nonvital, Immature permanent Incisors treated with a mineral trioxide aggregate plug and adhesive restorations: a case series from a private endodontic practice. J Endod. 2017 Aug;43(8):1370-1337.
14. Žižka R, Buchta T, Voborná I, Harvan L. Root Maturation in Teeth Treated by Unsuccessful Revitalization: 2 Case Reports. J Endod. 2016 May;42(5):724-729.
15. Zicari F, Coutinho E, Scotti R, Van Meerbeek B, Naert I. Mechanical properties and micro-morphology of fiber posts. Dent Mater. 2013 Apr;29(4):45-52.
16. Vichi A, Vano M, Ferrari M. The effect of different storage conditions and duration on the fracture strength of three types of translucent fiber posts. Dent Mater. 2008 Jun;24(6):832-838.
17. Papadogiannis D, Tolidis K, Gerasimou P, Lakes R, Papadogiannis Y. Viscoelastic properties, creep behavior and degree of conversion of bulk-fill composite resins. Dent Mater. 2015 Dec;31(12):1533-1541.
18. Tay F, Horashi N, Pashley D, *et al*. Bondability of resilon to a Methacrylate-Based Root Canal Sealer. J Endod. 2006 Feb;32(2):133-137.
19. Belli S, Eraslan O, Eskitascıoglu G. Effect of different treatment options on biomechanics of immature teeth: A finite element stress analysis study. J Endod. 2018 Mar;44(3):475-479.
20. Singhal S, Antonson D, Antonson S, Muñoz C. Depth of cure of bulk-fill composites- ISO 4049 vs. Vickers hardness test. Dent Mater. 2013;29:e32-e33.
21. Helvatjoglu-Antoniades M, Papadogiannis Y, Lakes RS, Dionysopoulos P, Papadogiannis D. Dynamic and static elastic moduli of packable and flowable composite resins and their development after initial photo curing. Dent Mater. 2006 May;22(5):450-459.
22. Unterbrink G, Liebenberg W. Flowable resin composites as filled adhesives: literature review and clinical recommendations. Quintessence Int. 1999 Apr;30(4):249-257.
23. Leevailoj C, Cochran M, Matis B, Moore B, Platt J. Microleakage of posterior packable resin composites with and without flowable liners. Oper Dent. 2001 May;26(3):302-307.
24. Czasch P, Ilie N. *In vitro* comparison of mechanical properties and degree of cure of bulk-fill composites. Clin oral Investig. 2013 Jan;17(1):227-235.
25. Chen H, Manhart J, Hickel R, Kunzelmann K. Polymerization contraction stress in light-cured packable composite resins. Dent Mater. 2001 May;17(3):253-259.
26. Leung R, Fan P, Johnston W. Post-irradiation polymerization of visible light-activated composite resin. J Dent Res. 1983 Mar;62(1):363-365.
27. Par M, Gamulin O, Marovic D, Klaric E, Tarle Z. Effect of temperature on post-cure polymerization of bulk-fill composites. J Dent. 2014 Oct;42(10):1255-1260.
28. Zorzin J, Maier E, Harre S, *et al*. Bulk-fill resin composites: polymerization properties and extended light curing. Dent Mater. 2015 Mar;31(3):293-301.
29. Ilie N, Stark K. Curing behaviour of high-viscosity bulk-fill composites. J Dent. 2014 Aug;42(8):977-985.
30. Alshali RZ, Silikas N, Satterthwaite JD. Degree of conversion of bulk-fill compared to conventional resin-composites at two time intervals. Dent Mater. 2013 Sep;29(9):213-217.