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Comparative evaluation of interfacial gaps at the dentin-restorative interface using different bulk fill composites through optical coherence tomography

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Abstract
The main problem faced by composites is polymerization shrinkage and stresses which depends on multiple factors such as the configuration factor, composition of resin composites, material properties, various incremental placement techniques and different modes of curing. The aim of this *in-vitro* study was to evaluate interfacial gaps at dentin- restorative interface with different Bulk-fill composites using a new non-invasive technique, optical coherence tomography (OCT). Our null hypothesis was that there would be no difference in marginal adaptation to the cavity floor between different bulk fill resin composites.

Keywords: Comparative evaluation, interfacial gaps, Optical coherence tomography

Introduction

Resin-based composites have been successfully used in dentistry for many years and widely replaced amalgam as a posterior restoration [1]. Reasons for this relatively rapid and significant change in restorative dentistry include individual patient desires for non-metal, natural-looking restorations, less invasive nature of composite restorations & significant improvement in composite resin material leading to increased durability and longevity. A major drawback of composites is polymerization shrinkage, which generates stress at the tooth-restoration interface that might weaken the restoration integrity, resulting in debonding when the shrinkage stress surpasses the bond strength [2], and lead to gap formation. Gaps and lack of integrity at the tooth-restoration interface may affect the success of an adhesive restoration. Gap formation may result from excessive contraction stresses at the interface between the restoration and the tooth [2], which can be a consequence of the polymerization rate of the material and the magnitude of polymerization contraction [3]. The loss of interfacial seal may result in bacterial micro leakage, secondary caries and hypersensitivity of the restored vital tooth, eventually leading to failure of the treatment [4]

In a fast-paced restorative practice, it would not be uncommon to find multiple patients each day who require several posterior restorations to be done in one appointment. The ability to place these restorations in a simple, predictable and timely fashion would be beneficial to not only the clinician, but also to the patients. In light of this, a group of new products were recently introduced, known as “Bulk-fill composites". Bulk-filling techniques have become more widely used following the development of materials with improved curing [5], controlled polymerization contraction stresses [6], and reduced cuspal deflection [6]. Using this approach, the number of increments required to fill a cavity is reduced in comparison with traditional incremental filling techniques. In contrast to the maximum 2-mm increments recommended for conventional resin composites, manufacturers recommend 4-or 5-mm increments of the bulk-fill resin composites. The rationale of the bulk-fill resins is to reduce clinical steps by filling the cavity in "single" increment leading to a reduced porosity and a uniform consistency for the restoration, further reducing the clinical time taken and cost factor for the patient [7].

In this in-vitro study, we evaluated gap formation under various bulk fill composites representing their internal adaptation abilities and comparing them with an incremental fill composite through optical coherence tomography.

Materials and Methods

Eighty freshly extracted human mandibular molars extracted for periodontal reasons were disinfected by immersion in 5% Sodium hypochlorite (Shivam Industries, Jammu, India) for 30 minutes. Soft tissue tags attached to root surfaces were removed by periodontal curette, calculus and attached bone fragments, if any, were removed by ultrasonic scaler. Teeth were stored immersed in distilled water at 4°C until use. The occlusal cusps were grounded to obtain a flat occlusal table in enamel using a metallic disc attached to a straight handpiece and then polished with silicon carbide papers. This was aimed to eliminate any possible superficial enamel cracks, and create a flat surface for standard cavities. To facilitate tooth preparation, disposable sample collection tubes were loaded with vinyl-polysiloxane impression material (Affins, Coltene, Whaledent) approximately 3mm below the rim. Tooth was then placed in the impression material upright with 2-3 mm of coronal structure visible. Tubes were then placed in a customized jig for tooth preparation. Standardized cylindrical class-I cavity with the floor located in dentin having the dimensions (4 mm depth x 4mm width) were prepared on all teeth. The roots of the teeth were sectioned, and the remaining coronal portions were trimmed into a block shape with the parallel opposing walls (buccal, lingual, mesial and distal) perpendicular to the sidewalls (occlusal and cervical). The tooth preparation was started using diamond round point with diameter of 1mm, followed by straight fissure point with diameter of 1.5 mm attached to an air turbine headpiece under copious cooling water. The burs were replaced after every five preparations in order to maintain the cutting efficiency. Easy Bond self-etch (3M ESPE) bonding agent was used according to the manufacturer's instructions. It was applied on the cavity surface for 20 seconds, dried with gentle air pressure for 5 seconds and irradiated with a LED light curing unit for 10 seconds. A single adhesive was used in the study to emphasize the influence of restorative composites. The prepared teeth were divided into 4 groups on the basis of restorative material used with 20 teeth in each group; Group 1: Filtek Z350 XT restorative material (n=20), Group 2: Tetric N-ceram Bulk Fill (n-20), Group 3: SONICFILL Bulk fill (n=20), Group 4: Surefil SDR Bulk fill (n=20).

Group 1: Filtek Z350 XT Group. Nanocomposite was placed in incremental manner with first increment of 2 mm thickness and then light cured for 20 seconds using LED light curing unit in continuous motion. Subsequently another increment of 2 mm thickness was placed followed by light curing for 20 seconds using continuous mode.

Group 2: Tetric N-ceram Bulk Fill. Composite was placed in bulk and properly condensed in a single increment of 4 mm thickness followed by light curing for 20 seconds using LED light cure unit in continuous mode.

Group 3: Sonicfill Bulk fill. It is a sonic-activated bulk fill composite. The unidose tip was attached to the specially designed handpiece. The tip was placed at the floor of the cavity and due to the activation by sonic energy, composite viscosity drops enabling its flow into the cavity preparation. When the sonic energy is stopped, the composite returns to a more viscous, non-slumping state for carving and contouring. The whole cavity was filled upto 4 mm and then light cured for 20 seconds using LED light curing unit in continuous mode.

Group 4: Surefil SDR Bulk fill. It is a low stress bulk fill composite. The compule tip was placed at the floor of the cavity and the whole cavity was filled upto 4mm. The composite was then light cured for 20 seconds using LED light curing unit in continuous mode.

After total polymerization, all the specimens were finished and polished with swiss-flex discs in sequential manner as per manufacturer's instructions in order to remove the excess of resin and standardize the surface. The restored cavities were stored in a hydrated state at the room temperature.

A specimen holder was fabricated for each specimen to individually fix it to the OCT worktable. The scanning probe connected to the SS-OCT will be positioned over the occlusal table, with scanning beam oriented at about 90◦ with respect to the occlusal plane.

Every obtained image was analyzed by using ImageJ software (version 1.42q). A custom computer code was developed as a plug in for ImageJ based on a binarization process to facilitate the image analysis procedure and distinguish pixel clusters with higher brightness indicating gaps or unsealed interfaces at the cavity floor. The total interfacial gap of the cavity floor will be calculated as the ratio between the gap length at all cross sections and the cavity floor length at all cross sections.

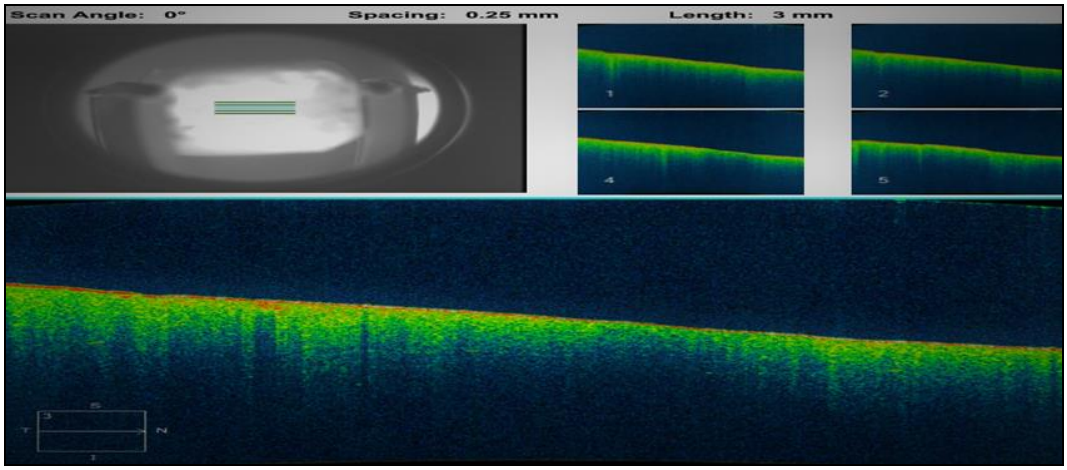

Fig 1: OCT scanning image of the cavity floor–composite interface once acquired in high speed and enhanced depth imaging modes.

Statistical Analysis

The recorded data was compiled and entered in a spreadsheet (Microsoft Excel) and then exported to data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). Analysis of variance (ANOVA) with least significant difference (LSD) test was employed for comparing gap length and gap

percentage. Graphically the data was presented by bar diagrams. A P-value of less than 0.05 was considered statistically significant.

Results

The results showed that the mean gap length of sonic fill composite was lesser among all the groups. The mean gap length of Sonic fill (71.48 ±16.56) was lower than Surefil SDR (129.68 ±58.90) which was followed by Tetric-n-ceram (199.06±88.49) and the greatest mean gap length was of Filtek z350xt (261.78 ±51.43). On comparison, there was a statistically significant difference found among all groups *(P-value<0.05)*. On comparison of the gap percentage, the results showed that the mean gap percentage of Sonic fill composite was also lesser among all the groups. The mean gap percentage of Sonic fill (7.15 ±1.66) was lower than Surefil SDR (12.96 ±5.89) which was followed by Tetric-n-ceram (19.90±8.84) and the greatest mean gap percentage was of Filtek z350xt (26.17 ±5.14). On comparison, there was a statistically significant difference found among all groups *(P-value<0.05)*.

Table 1: Showing average gap length among various groups

Gap length	N	Mean	SD	95% confidence interval for Mean	
IF	20	261.78	51.43	237.71	285.85
SDR	20	129.68	58.90	102.12	157.24
SF	20	71.48	16.56	63.72	79.23
TNC	20	199.06	88.49	157.64	240.47

Table 2: Showing average gap percentage among various groups

Gap percentage	N	Mean	SD	95% confidence interval for mean	
IF	20	26.16	5.16	23.74	28.58
SDR	20	12.97	5.89	10.21	15.73
SF	20	7.15	1.66	6.37	7.93
TNC	20	19.91	8.85	15.76	24.05

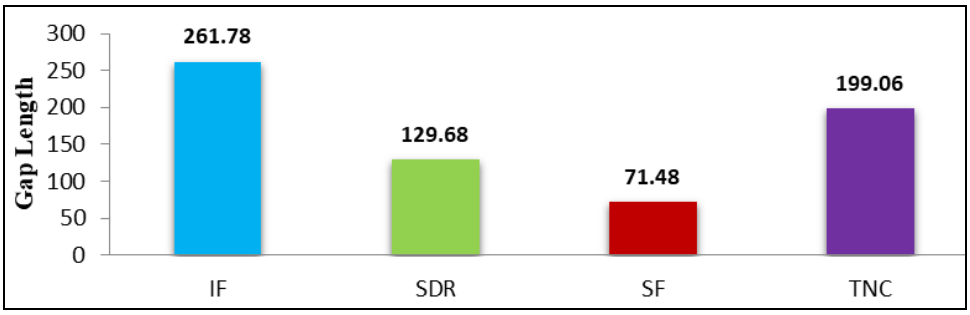

Fig 1: Showing average gap length among various groups

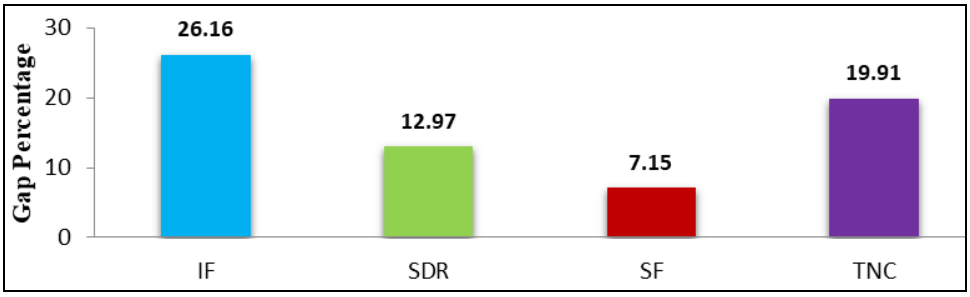

Fig 2: Showing average gap percentage among various groups

Discussion

As a result of an increased focus on the aesthetic qualities of dental restorations, and in response to enhancements in the resin technologies that are available, tooth-colored resin composite materials are increasingly being used for posterior teeth, instead of the more traditional amalgam fillings.[7] Recently, a new class of composites known as bulk-fill composites have been developed to simplify the rather time-consuming incremental technique. The concept of ''bulk-filling'' a preparation is not a novel idea [8], and has been evaluated numerous times in the literature [9]. Historically, several disadvantages of bulk-filling preparations with light-cured composites are recognized: the inability to adequately cure composite to depths greater than 2 mm, challenges related to preparation design on the C-factor, as well as potential complications due to polymerization shrinkage and increased gap formation, both internally and at the cavosurface margins [10, 11]. Opposed to conventional composites, newer bulk-fill composites generate a lower polymerization shrinkage stress and have higher light transmission properties due to reduction of light scattering at the filler–matrix interface by either decreasing the filler amount or increasing the filler size [12]. Therefore, bulk-fill composites are claimed by the manufacturers to be used for increments of up to 4-5 mm thickness. Extensive review of the literature showed that there was very limited data available which measured and evaluated the gaps formation of these bulk fill composites especially Sonicfill composite. So, we did the study utilizing three bulk fill i.e. Surefil SDR, Tetric-N-Ceram & Sonicfill composite and compared them with a conventional incremental composite using Filtek Z350XT in the study which is also a nanohybrid composite like other bulk fill material used in this study.

Interfacial gap detection has been widely studied, and several methods have been proposed for determining marginal or interfacial adhesive defects. One commonly used method entails highlighting microleakage using an organic dye or silver nitrate as a tracer [13], generally used to investigate the quality of adhesives on the basis of the marginal gaps [14] or interfacial gaps formed at the tooth restoration interface [15]. The disadvantages of microleakage analysis are that it is an invasive semiquantitative analysis and it shows only a limited

representation of 3-dimensional geometry [16]. Marginal analysis is another method used to investigate interfacial gaps because it enables monitoring and multiple measurements of marginal integrity with the use of replicas [17], but it cannot cover the entire adhesive area of restorations and does not allow nondestructive internal evaluation of interfaces. Micro–computed tomographic imaging allows a detailed display of interfacial discrepancies detectable by x-ray. However, it requires long measurement times, and over-drying of specimens during scanning can cause deformation, resulting in false positives [18]. For these reasons, OCT imaging was used in the present study to evaluate the presence of interfacial gaps between the composite and cavity floor. OCT imaging can analyze to a depth of about 4-6 mm [19], so it was necessary to cut samples into block shape after the restoration to clearly visualize the cavity floor interface.

The results of our study showed that there was a significant difference between different bulk fill composites in their adapting capabilities to the cavity floor dentin. None of the restorations were gap free as shown by Davidson CL & Feilzer AJ (1997) [20] due to polymerization shrinkage and polymerization shrinkage stress generated in every polymer-based restorative. In our study, Bulk fill composites exhibited less percentage of gap formation as compared to the incremental control group i.e, Filtek Z350 XT. This is in accordance with the study by El-damanhoury *et al* [2013] [18]

SonicFill composite exhibited lowest percentage of gap formation as compared to other bulk fill composites. According to Ibarra E *et al* in 2013[21], Sonicfill has lower volumetric polymerization shrinkage (1.88%) than the long-established micro-hybrid resin composite Z250 (3M Espe) and has very low porosities than other bulk fill composites. Amer Tiba *et al* in 2013[22], evaluated several physical and mechanical properties of different bulk-fill materials, comparing the materials with one another as well as with traditional increment–fill resin based composites and found that high-viscosity SonicFill had the lowest value for polymerization shrinkage stress as compared with the other resin-based composites.

In this study, Surefil SDR showed significantly less gap formation as compared to Tetric-N-ceram and Filtek Z350 XT but more than Sonicfill composite. Rheine [23] suggested that SDR is the flowable composite which can be used as a bulk fill base material in increments of up to 4 mm, as also recommended by the manufacturer. The main difference lies in a modulator (on the activated photoactive group) that is incorporated into a urethane-based dimethacrylate which reduces polymerization stress [24] by slowing the radical polymerization rate. Poggio *et al* [25] conducted an *in vitro* study in which high microleakage values were recorded for SDR as compared to SonicFill when "deep" Class II cavities were prepared and restored with gingival cavosurface margin below the cementoenamel junction.

Conclusion

Within the limitations of this in-vitro study we conclude that none of the materials tested were able to prevent gap formation. However, the percentage of gap formation was significantly reduced in the high viscosity sonic fill composite followed by Surefil SDR as compared to other composites tested in our study.

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