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메탈브라켓 부착시 벌크필복합레진의 전단결합강도 평가

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〈Abstract〉

Evaluation of bulk-fill resin composite on the shear bond strength of metal brackets

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본 연구는 벌크필복합레진의 교정용메탈브라켓에 대한 전단결합강도를 평가하였다. 본 연구에서는 3 종의 벌크필복합레진 (Filtek Bulk Fill, Tetric N-Ceram Bulk Fill, SonicFill)을 접착제로 사용하였고, 대조군으로 Transbond XT 를 사용하였다. 광조사를 위해 473 nm 레이저 (LVI-VA457-100)와 2 종의 광조사기 (Optilux 501, L.E.Demetron)를 사용하였다. 교정용브라켓을 발거된 상악소구치에 부착하고 광조사한 후, 광중합이 완료된 시료의 결합강도를 측정하고 파절면을 관찰하였다. 그 결과 모든 광조사기군에서 Transbond XT 군이 다른 벌크필복합레진군보다 높은 결합강도를 보였다 (p 〈0.05). 벌크필복합레진군에서 SonicFill 군은 다른 벌크필복합레진군보다 유의하게 높은 전단결합강도 값을 보였다. 광조사기군간에 결합강도는 유의한 차이가 나타나지 않았다 (p = 0.061). ARI 점수는 접착군간에는 유의한 차이가 발생하였지만 (p 〈0.001), 광조사기군간에는 유의한 차이가 나타나지 않았다 (p = 0.099). 모든 광조사기군에서 벌크필복합레진군은 임상적으로 허용가능한 결합강도 (5.9-7.8MPa)를 보여 교정용브라켓을 부착시 접착제로 사용될 수 있다는 것을 확인하였다.

주제어: 벌크필 복합레진, 전단결합강도, 접착제, 메탈브라켓

Ⅰ. INTRODUCTION

In 1962, Bowen of the American Dental Association developed a new type of composite material. Bisphenol-A glycerylmethacrylate (bis-GMA), which is called Bowen's resin, and an organic silane coupling agent were his great achievements (Anusavice, 2003). These new composites solved problems such as excessive thermal expansion and contraction, the poor wear resistance of acrylic resins, and a bond between the filler particles and the resin matrix.

However, commonly used resin-based composites (RBC) still have major drawbacks such as high polymerization shrinkage (Davidson & Feilzer, 1997; Ozer et al., 2014). Polymerization stress is caused by volumetric contraction, which causes the bond integrity to result in secondary caries and restoration loss (Zorzin et al., 2015; Taneja et al., 2016). Many clinical methods have been proposed for reducing polymerization shrinkage. The layering technique that sequentially fills resin composite into the tooth cavity and performs light curing reduces polymerization shrinkage effectively by reducing the C-factor (ratio of bonded to unbonded surface) (Opdam et al., 1998; Park et al., 2008). Still, this incremental layering method of filling the cavity

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with resin composite has caused problems such as incorporation of voids, contamination between composite layers, bonding failure between layers (Abbas et al., 2003), increased deformation of the restored tooth (Versluis et al., 1996), and long working time. Another limitation in the use of resin composite is an insufficient depth of cure (Sakaguchi et al., 1992). Although the light curing time varies in different RBCs and light curing units (LCUs), typical Quartz-tungsten-halogen (QTH) and light-emitting diode (LED) curing lights require 20 to 40 seconds to cure resin composites (Christensen et al., 2000), and the depth of cure of resin composites is 2 mm (Christensen et al., 2000; Moore et al., 2008).

To overcome these limitations, a new type of RBCs was developed (Zorzin et al., 2005; Ilie et al., 2013b). This newly developed type of RBCs has a comparable flexural strength to nano-and microhybrid RBCs and a higher flexural strength than flowable RBCs (Ilie et al., 2013a). These bulk-fill RBCs have less shrinkage stress and a lower shrinkage rate (Ilie & Hickel, 2011), reduced cuspal deflection (Moorthy et al., 2012), and similar marginal adaptation (Campos et al., 2014) compared with traditional RBCs. These bulk-fill RBCs show improvement in light transmittance due to a reduction in the amount of filler and increased filler size, which enhances the depth of cure (Ilie et al., 2013a). Because curing an RBC with a 4mm bulk for 20 seconds can maintain the degree of cure and micro-mechanical properties (Czasch & Ilie, 2012), this bulk-fill RBC allows the use of up to 4 mm increments of material (Ilie et al., 2013a; Ilie et al., 2013b; Finan et al., 2013; Garoushi et al., 2013; Li et al., 2015). Therefore, the layering process can be skipped with this bulk-fill RBC while maintaining a high shear strength (Ilie et al., 2014) and saving precious chair time (Garoushi et al., 2013).

Furthermore, flowable bulk-fill RBCs such as SureFil SDR (Dentsply, Milford, DE, USA) have been introduced to have low, slow elastic modulus development and low-stress polymerization without compromising the cure depth (Burgess et al., 2010). SureFil SDR with the low-stress behavior of flowable bulk-fill RBCs is suitable for both post-cementation and core build-up (Giovannetti et al., 2012). Traditional RBCs have been used in diverse dentistry fields such as posterior occlusal restoration, sealing pits and fissures, porcelain veneer cementation, and other dental restoration cementation. Considering the availability for both post-cementation and core build-up, bulk-fill RBCs can be used in cementation like traditional RBCs.

However, there is limited knowledge about the bonding properties of bulk-fill RBCs. Therefore, the aim of this study was to evaluate and compare the shear bond strength (SBS) of orthodontic brackets bonded with bulk-fill RBCs. The tested null hypotheses were that: (1) there would be no significant difference in the shear bond strength (SBS) among the four materials (bulk-fill RBCs or conventional adhesive cement) and (2) there would be no significant difference in the shear bond strengths (SBS) among light-curing units (LCU).

II. MATERIAL AND METHODS

1. Specimen preparation

Three bulk-fill resin composites were investigated in this study (Table 1). One was flowable bulk-filling resin composite (Filtek Bulk Fill). Two were packable bulk-fill resin composites (Tetric N-Ceram, SonicFill). A conventional adhesive cement (Transbond XT) was used as a control. One hundred and eighty sound human premolar teeth extracted for orthodontic reasons were utilized. The connective tissue of the teeth was removed, and the teeth were stored in a 0.2% thymol solution. The teeth were rinsed with tap water for 20 seconds.

Table 1. Characteristics of materials tested in this study

Adhesive cement	Manufacturer	Resin matrix	Filler	Filler content (wt%)	Lot No.
Transbond XT	3M Unitek, Monrovia, CA, USA	Bis-GMA 10-20wt% Bis- EMA 5-10wt%	Silane treated quartz, silica	77	CM7DI
Filtek Bulk Fill	3M ESPE St. Paul, MN, USA	UDMA10-20wt% Substituted dimethacrylate10-20wt% BisEMA-61-10wt% BisGMA1-10wt% TEGDMA〈1wt%	Ziriconia/silica filler, Ytterbium trifluoride	64.5	N536127
Tetric N-Ceram Bulk Fill	Ivoclar Vivadent, Schaan, Liechtenstein	Bis-GMA 3-10wt% Bis-EMA 3-10wt% UDMA 3-10wt% 19.7wt%organicmatrixin total	Polymer filler, Barium glass, Ytterbium trifluoride, Mixed oxide	78(including 17% polymer filler)	S09719
SonicFill	Kerr, Orange, CA, USA	Bis-GMA 1-5wt% TEGDMA 1-5wt% EBPDMA 1-5wt%	Sio^2, glass, oxide	83.5	4822738

Abbreviation: Bis-EMA, bisphenol-A polyethylene glycol diether dimethacrylate; Bis-GMA, bisphenol-A diglycidyl ether dimethacrylate; EBPDMA, ethoxylated bisphenol-A-dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.

2. Light-curing conditions

Light-curing was performed with three LCUs: a QTH unit (Optilux 501, Kerr, Danbary, CT, USA), a LED unit (L.E.Demetron, Kerr, Danbury, CT, USA), and a diode-pumped solid state (DPSS) laser (LVI-VA473-100, LVI Tech, Seoul, South Korea). The output intensity of the QTH and LED units was approximately 850mW/cm^2, as measured using built-in radiometers. The output power and spot size of the DPSS laser were 150 mW (measured using a power meter; PM3/FILELDMAX, Coherent, Portland, OR, USA) and 6 mm, respectively, giving a resultant intensity of 530 mW/cm^2.

Stainless steel premolar brackets (Tomy, Tokyo, Japan) were used with a 0.022-inch slot. The surface area of the bracket base was 12.89mm^2 (the average of five brackets). The teeth were randomly divided into four different adhesive cement groups: (1) Filtek Bulk Fill, (2) Tetric N-Ceram Bulk Fill, (3) SonicFill, and (4) Transbond XT. These groups were divided into three subgroups by light-curing units—(1) QTH, (2) LED, and (3) DPSS. The enamel surface was etched, rinsed, and dried for 15 seconds, and a primer (Transbond XT, 3M Unitek, Monrovia, CA, USA) was uniformly applied to the enamel surface. The adhesive cement was applied to the bracket base, and then the bracket base was placed onto the enamel surface and pressed with an equal force. The excessive adhesive cement was eliminated carefully, and light curing was performed at the mesial and distal sides for 20 seconds each. After attaching the brackets, the specimens were mounted in orthodontic acrylic resin in plastic molds and were stored in distilled water for 24 h at 37℃.

3. Bracket deboning and ARI

After 24 h, the SBS of each group of specimens was tested using a universal testing machine (Instron 3345, Instron Corporation, Canton, M, USA) with crosshead speeds of 1 mm/min. The maximum load to debond a

Table 2. Shear bond strength (SBS) of the different groups[a]

Adhesive cement	LCU			*P*-value
	QTH[a]	LED[a]	DPSS[a]	
Transbond XT[1]	16.73 ± 2.66	15.76 ± 2.98	14.67 ± 3.57	
Filtek Bulk Fill[3]	12.89 ± 1.78	11.86 ± 2.10	11.57 ± 2.41	α = 0.061
Tetric N-Ceram Bulk Fill [3]	12.75 ± 2.04	11.98 ± 3.27	10.83 ± 2.41	$\beta < 0.001$ $\alpha \times \beta$ = 0.962
SonicFill[2]	13.74 ± 3.41	13.79 ± 3.34	13.39 ± 3.66	

[a]Statistically significant difference on adhesive cement is shown by superscript numbers[1, 2], and on LCU by superscript letter[a]. Same letters or numbers do not indicate a significant difference ($P > 0.05$). α and β on *P*-values denote LCU and adhesive cement, respectively.

bracket was recorded in Newtons and calculated in MPa and then was divided into the bracket base surface. After debonding a bracket, the adhesive cement remnant index (ARI) was recorded using a stereoscopic microscope x 10. ARI was classified as the amount of adhesive cement remaining on the tooth surface: (1) all adhesive cement remaining on the tooth; (2) morethan 90% of the adhesive cement remaining on the tooth; (3) between 10% and 90% of the adhesive cement remaining on the tooth; (4) less than 10% of the adhesive cement remaining on the tooth; and (5) no adhesive cement remaining on the tooth (Park et al., 2013).

4. Statistical analysis

The mean SBS of the groups was compared by two-way analysis of variance (adhesive cements and LCU) with a significance value of $p > 0.05$. The significance of the mean difference between the groups was calculated by the Duncan post-hoc test. Statistical calculations were performed using PASW Statistics 18 software (SPSS Inc., Chicago, IL, USA). Kruskal-Wallis test was used for comparing ARI score. Statistical significance was set at $p < 0.05$.

Ⅲ. RESULTS

1. Shear bond strength

The SBS for all groups is shown in Table 2. For all LCUs (14.67 - 16.73 MPa), Transbond XT showed a higher SBS than the bulk-fill resin composites. For all LCUs, the three bulk-fill resin composites showed clinically acceptable SBS values (10.83 - 13.79 MPa). Analysis of variance revealed significant differences between the bulk-fill RBC groups, with SonicFill having a significantly higher SBS than the other two bulk-fill resin composites ($p < 0.05$). However, LCUs had no significant impact on the SBS ($p = 0.061$).

2. Adhesive cement remnant index

The distribution of failure modes after SBS testing is shown in Table 3. Figure 1 show the representative photographs of the bracket surface after debonding. In all groups, some or all of the adhesive cement remained on the bracket (ARI score 4 and 5). ARI scores were significantly different among adhesive cement groups ($p < 0.001$). As for the adhesive cement groups, the highest percentage of ARI score 5 (all adhesive cement remaining on the bracket) was observed in the SonicFill group (75.6%), followed by the Transbond XT group (68.9%), the Tetric N-Ceram group (42.2%), and the Filtek Bulk Fill

Table 3. Adhesive cement remnant index (ARI) scores for the different groups

Adhesive cement	LCU	ARI Score				
		1	2	3	4	5
Transbond XT	QTH	0(0%)	0(0%)	1(6.7%)	1(6.7%)	13(86.7%)
	LED	0(0%)	0(0%)	0(0%)	4(26.7%)	11(73.3%)
	DPSS	0(0%)	2(13.3%)	1(6.7%)	5(33.3%)	7(46.7%)
Filtek Bulk Fill	QTH	0(0%)	1(6.7%)	1(6.7%)	8(53.3%)	5(33.3%)
	LED	0(0%)	0(0%)	3(20.0%)	6(40.0%)	6(40.0%)
	DPSS	1(6.7%)	0(0%)	6(40.0%)	4(26.7%)	4(26.7%)
Tetric N-Ceram	QTH	0(0%)	0(0%)	0(0%)	10(66.7%)	5(33.3%)
	LED	1(6.7%)	1(6.7%)	0(0%)	6(40.0%)	7(46.7%)
	DPSS	2(13.3%)	1(6.7%)	0(0%)	5(33.3%)	7(46.7%)
SonicFill	QTH	0(0%)	0(0%)	1(6.7%)	2(13.3%)	12(80.0%)
	LED	0(0%)	0(0%)	0(0%)	3(20.0%)	12(80.0%)
	DPSS	0(0%)	0(0%)	1(6.7%)	4(26.7%)	10(66.7%)
p - values		α = 0.099 β 〈 0.001				

[a]Score 1, all adhesive cement remaining on the tooth; score 2, more than 90% of adhesive cement remaining on the tooth; score 3, 10% to 90% of adhesive cement remaining on the tooth; score 4, less than 10% of adhesive cement remaining on the tooth; score 5, no adhesive cement remaining on the tooth. α and β on *P*-values denote LCU and adhesive cement, respectively.

group(33.3%). However, ARI scores were not significantly different among the light-curing units (p = 0.099).

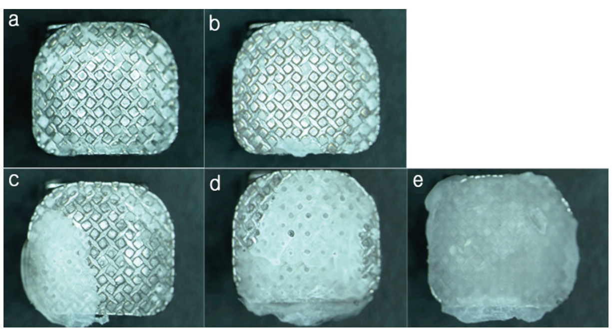

Figure 1. The photographs of specimen showing the Adhesive cement remnant index.
(a: score 1, b: score 2, c: score 3, d: score 4, e: score 5).

Ⅳ. DISCUSSION

The first null hypothesis that adhesive cement (bulk-fill RBCs and conventional adhesive cements) has no significant influence on shear bond strength (SBS) has to be rejected. All three bulk-fill RBCs had a lower SBS value than conventional adhesive cement Transbond XT. When the brackets were attached using bulk-fill RBCs, SonicFill had a significantly higher SBS than the other two bulk-fill RBCs. However, the SBS of all bulk-fill RBCs was the higher than the SBS value recommended for adhesive cements (5.9 - 7.8MPa), indicating that bulk-fill RBCs can be used to attach orthodontic brackets. In a previous study, when bulk-fill RBCs and conventional RBCs were bonded to dentin, the SBS of conventional RBCs was higher than that of bulk-fill RBCs, and the SBS of SonicFill (12.19 ± 5.48 MPa) was slightly higher than that of Tetric EvoCeram Bulk Fill (11.16 ± 2.76 MPa)(Colak et al., 2016), similar to the findings of the present study.

Bulk-fill RBCs have been introduced into the market as a result of the demand for simple and convenient restoration procedures (Ilie et al., 2014; Caixeta et al., 2015). Bulk-fill RBCs are classified according to viscosity as low- and high-viscosity bulk-fill RBCs. Flowable, low-viscosity bulk-fill RBCs (SureFil SDR, Dentsply; Venus BulkFill, Heraeus Kulzer; x-trabase, VOCO; Filtek BulkFill, 3MESPE) entered the market first. Low-viscosity bulk-fill RBCs have weak physical properties; thus it is necessary to cap them with traditional RBCs. Later, high-viscosity bulk-fill RBCs were released (SonicFill, Kerr; Tetric EvoCeram Bulk Fill, Ivoclar Vivadent; X-traFil, VOCO) that do not require a capping layer and can, therefore, be used as a single step bulk filling material (Braga et al., 2005).

RBCs have viscoelastic behavior and convert during polymerization from a viscous plastic structure to a rigid elastic structure (Caixeta et al., 2015). Polymerization shrinkage occurs in RBCs while bonding composites to dental tissue, causing a problem with the stability of the restoration (Caixeta et al., 2015). In composites, development of polymerization shrinkage stress (PSS) is influenced by a multiplicity of factors such as the type of filler and content, filler/matrix interaction, type of monomer, and the degree and rate of polymerization (Braga et al., 2005; Caixeta et al., 2015). Increased inorganic filler decreases the concentration of double bonds, which reduce volumetric contraction (Gonçalves et al., 2011).The reduced polymerization rate due to high inorganic filler content was related to a high modulus of elasticity (Gonçalves et al., 2011). In conventional RBCs, higher filler content resulted in a higher modulus of elasticity (Ilie & Hickel, 2009; Gonçalves et al., 2010; Ilie et al., 2013). Similarly, in bulk-fill RBCs, higher filler content resulted in a higher modulus of elasticity (Ilie et al., 2013a). On the other hand, materials with reduced elastic modulus due to lower filler content will result in greater deformability under masticatory stresses when placed in a load-bearing area, which will cause disastrous failure (Ilie et al., 2013a).

The volumetric percent of the filler weight of Filtek BulkFill (64.5%) used in the present study was remarkably lower than that of the other RBCs. It is assumed that this lower volumetric percent of the filler weight significantly influenced the lower SBS of the Filtek BulkFill. Tetric N Ceram Bulk Fill, a high-viscosity bulk-fill RBC, had a significantly lower SBS than SonicFill, also a high-viscosity bulk-fill RBC. The volumetric percent of the filler weight of Tetric N-Ceram Bulk Fill (78%) is high, but polymer filler (16%) is included within the filler content. This polymer filler may have influenced the lower SBS of the Tetric N-Ceram Bulk Fill. SonicFill has higher filler content (83.5%) than the other two bulk-fill RBCs and also had higher SBS values, which is accordance with a previous study (Colak et al., 2016).

The effect of inorganic filler content on PSS is still under debate. That is, in a previous study, an increase in filler content disrupted polymeric chain propagation, which resulted in increased polymerization shrinkage stress (Braga et al., 2005). In another previous study, an increase of the filler content of RBCs was related to less PSS, which can be explained by the reduced volumetric shrinkage observed in heavily filled composites (Gonçalves et al., 2010).

An increased degree of conversion (DC) in RBCs results in increased polymerization shrinkage and elastic modulus. The bis-GMA (2,2-bis[4-(2-hydroxy-3-methacrylyloxypropoxy) phenyl] propane) concentration influences the increase of elastic modulus (Asmussen et al., 1998).That is, a monomer matrix such as bis-GMA, triethylene glycol dimethacrylate (TEGDMA), or urethane dimethacrylate (UDMA) influences the conversion of resin composites (Zorzin et al., 2015).

The high viscosity of bis-GMA reduces mobility, which reduces DC (Zorzin et al., 2015).To reduce the high viscosity of bis-GMA, TEGDMA and UDMA were added to the resin matrix. Low molecular weight monomers such as TEGDMA reduce the viscosity of resin composites and enhance the %DC but increase PSS and polymerization volume shrinkage (Zorzin et al., 2015). In order to reduce viscosity without increasing the TEGDMA content, high molecular weight monomers such as UDMA and ethoxylated dimethacrylate have been used (Zorzin et al., 2015).

The bonding ability to tooth substrate could also be influenced by the composition of the agents. In RBCs, the main factors that influence the bonding to tooth tissues are the DC, wettability, and shrinkage stress (Moraes et al., 2008).With a higher DC, the mechanical properties are excellent, which improves bonding to the tooth tissues (Moraes et al., 2008). Filtek BulkFill and Tetric EvoCeram Bulk Fill include bisphenol-A polyethylene glycol diether dimethacrylate (bis-EMA) and UDMA as a resin matrix; on the other hand, SonicFill includes TEGDMA and ethoxylated bisphenol-A-dimethacrylate, which have a low molecular weight, as a resin matrix. Bis-EMA and UDMA have a higher molecular weight and a stiffer structure than TEGDMA. The high viscosity of bis-EMA and UDMA reduces wettability with the substrate surface and disturbs adhesion, which might influence the low SBS of Filtek BulkFill and Tetric EvoCeram Bulk Fill (Moraes et al., 2008).

In traditional RBCs, the filler content is increased in order to enhance the mechanical properties, and the filler size is decreased in order to improve aesthetics. On the other hand, bulk-fill RBCs have a smaller filler amount and a larger filler size (Colak et al., 2016).A reduction in filler content was related to a reduction of hardness (Ilie et al., 2009).Commonly, hardness and the indentation modulus of high-viscosity bulk-fill RBCs with a high filler content were similar to conventional RBCs, and the hardness and indentation modulus of low-viscosity bulk-fill RBCs with a low filler content were lower than conventional RBCs (Bucutaet et al., 2014; Kim et al., 2015).Other than EvoCeram Bulk that contains 17% prepolymer filler, the increased filler content of bulk-fill RBCs increased the flexural strength (Ilie et al., 2013a). The flexural strength of bulk-fill RBCs is similar to nano-and hybrid RBCs and higher than flowable RBCs (Ilie et al., 2013a).

The filler content and transparency of RBCs are correlated. For all traditional RBCs and bulk-fill RBCs, lower transparency was correlated with higher filler content (Zorzin et al., 2015; Ilie et al., 2013a; Bucuta & Ilie, 2014).Other than SonicFill, which had a high filler content, the transparency of bulk-fill RBCs was the higher than that of traditional RBCs (Bucuta & Ilie, 2014). The transparency was affected by the difference of the refractive index between filler particles and resin matrix (Primus et al., 2002; Shortall et al., 2007).When the refractive index between the RBC components was similar, the transparency of the dental materials increased (Azzopardi et al., 2009).The good depth of cure with SonicFill may be due to a matching refractive index between the resin and filler, which enhances light transmission (Colak et al., 2016). In this study, the higher bond strength of SonicFill in comparison to the other bulk-fill RBCs could be attributed to the properties of the SonicFill (Colak et al., 2016).

In addition, the transparency of dental materials increases with a larger filler size (Ilie et al., 2013a).The filler dimension of bulk-fill RBCs increased (filler size〉20mm as observed in several materials such as x-trafil and x-trabase, VOCO, Cuxhaven, Germany; SureFil SDRflow, Dentsply Caulk, Milford, DE, USA; SonicFill, Kerr, Orange, CA, USA), which reduced the entire filler surface and filler-matrix interface as if filler content was the same. That is, light scattering at the filler-matrix interface reduced, which made light focus on the matrix and increased the depth of cure (Ilie et al., 2013a). In this study, SonicFill had a higher SBS value than the other bulk-fill RBCs. It was considered that this was attributed to DC enhancement due to an increase in the transparency according to the SonicFill filler size increase.

The second null hypothesis that the type of LCU has no significant influence on SBS was accepted. For all light-curing units, SBS values did not show a significant difference. Light curing with DPSS showed the comparable SBS values to QTH and LED. Thus, light curing with DPSS is possible in clinical practice (Park et al., 2013).

In ARI evaluation, Transbond XT (68.9%) and SonicFill (75.6%) displayed the highest SBS value and had a high distribution of ARI score 5 (all the adhesive cement remained on the bracket). In other words, more frequent failure occurred on the tooth-adhesive cement interface. Filtek Bulk Fill and Tetric N-Ceram displayed lower SBS values and had more frequent cohesive fractures within the adhesive cement.

V. CONCLUSION

The purpose of this study was to evaluate the utility of bulk-fill RBCs for bonding orthodontic brackets. In the present study, orthodontic brackets were bonded to the enamel surface using three different light curing units. For all LCUs, Transbond XT showed a higher SBS than bulk-fill resin composites. For all LCUs, the three bulk-fill resin composites showed clinically acceptable SBS values. There were significant differences between the bulk-fill RBC groups, as SonicFill had a significantly higher SBS than the other two bulk-fill resin composites. However, the LCUs showed no significant impact on the SBS. ARI scores were significantly different among adhesive cement groups, whereas ARI scores were not significantly different among LCUs. In all groups, some or all the adhesive cement remained on the bracket (ARI score 4 and 5).

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VI. REFERENCES

Abbas G, Fleming GJ, Harrington E, Shortall AC, Burke FJ (2003). Cuspal movement and microleakage in premolar teeth restored with a packable composite cured in bulk or in increments. J Dent 31:437-444.

Anusavice KJ (2003). Phillips' science of dental materials, eleventh ed., Saunders, p. 401.

Asmussen E, Peutzfeldt A (1998). Influence of UEDMA, BisGMA and TEGDMA on selected mechanical properties of experimental resin composites. Dent Mater 14:51-56.

Azzopardi N, Moharamzadeh K,Wood DJ, Martin N, Noort P van (2009). Effect of resin matrix composition on the translucency of experimental dental composite resins. Dent Mater 25:1564-1568.

Braga RR, Ballester RY, Ferracane JL (2005). Factors involved in the development of polymerization shrinkage stress in resin-composites: a systematic review. Dent Mater 21:962-970.

Bucuta S, Ilie N (2014). Light transmittance and micro-mechanical properties of bulk fill vs conventional resin based composites. Clin Oral Investig 18:1991-2000.

Burgess J, Cakir D (2010). Comparative properties of low-shrinkage composite resins. Compend Contin Educ Dent 31:10-15.

Caixeta RV, Guiraldo RD, Kaneshima EN, Barbosa AS, Picolotto CP, Lima AE, Gonini Júnior A, Berger SB (2015). Push-Out Bond Strength of Restorations with Bulk-Fill Flow and Conventional Resin Composites. Scientific World Journal 2015.

Campos EA, Ardu S, Lefever D, Jassé FF, Bortolotto T, Krejci I (2014). Marginal adaptation of class II cavities restored with bulk-fill composites. J Dent 42:575-581.

Christensen GJ (2000). Curing restorative resin: a significant controversy. J Am Dent Assoc 131:1067-1069.

Colak H, Ercan E, Hamidi MM (2016). Shear bond strength of bulk-fill and nano-restorative materials to dentin. Eur J Dent 10:40-45.

Czasch P, Ilie N (2012) In vitro comparison of mechanical properties and degree of cure of bulk fill composites. Clin Oral Investig 17:227-235

Davidson CL, Feilzer AJ (1997). Polymerisation shrinkage and polymerisation shrinkage stress in polymer-based restoratives. J Dent 25:435-440.

Finan L, Palin WM, Moskwa N, McGinley EL, Fleming GJ (2013). The influence of irradiation potential on the degree of conversion and mechanical properties of two bulk-fill flowable RBC base materials. Dent Mat 29: 906-912.

Garoushi S, Sailynoja E, Vallittu PK, Lassila L (2013). Physical properties and depth of cure of a new short fiber reinforced composite. Dent Mat 29:835-841.

Giovannetti A, Goracci C, Vichi A, Chieffi N, Polimeni A, Ferrari M (2012). Post retentive ability of a new resin composite with low stress behaviour. J Dent 40: 322-328.

Gonçalves F, Azevedo CL, Ferracane JL, Braga RR (2011). BisGMA/TEGDMA ratio and filler content effects on shrinkage stress. Dent Mater 27:520-526.

Gonçalves F, Kawano Y, Braga RR (2010). Contraction stress related to composite inorganic content (2010) Dent Mater 26:704-709.

Ilie N, Bucuta S, Dreaenert M (2013a). Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Oper Dent 38:618-625.

Ilie N, Hickel R (2009). Investigations on mechanical behaviour of dental composites. Clin Oral Investig 13: 427-438.

Ilie N, Hickel R (2011). Investigations on a methacrylate-based flowable composite based on the SDR technology. Dent Mater 27:348-355.

Ilie N, Kessler A, Durner J (2013b). Influence of various irradiation processes on the mechanical properties and polymerization kinetics of bulk-fill resin based composites. J Dent 41:695-702.

Ilie N, Rencz A, Hickel R (2012). Investigations towards nano-hybrid resin-based composites. Clin Oral Investig 17:185-193.

Ilie N, Schöner C, Bücher K, Hickel R (2014). An in-vitro assessment of the shear bond strength of bulk-fill resin composites to permanent and deciduous teeth. J Dent 42:850-855.

Kim EH, Jung KH, Son SA, Hur B, Kwon YH, Park JK (2015). Effect of resin thickness on the microhardness and optical properties of bulk-fill resin composites. Restor Dent Endod 40:128-135.

Li X, Pongprueksa P, Van Meerbeek B, De Munck J (2015). Curing profile of bulk-fill resin-based composites J Dent 43:664-672.

Moore BK, Platt JA, Borges G, Chu TM, Katsilieri I (2008). Depth of cure of dental resin composites: ISO 4049 depth and microhardness of types of materials and shades. Oper Dent 33:408-412.

Moorthy A, Hogg CH, Dowling AH, Grufferty BF, Benetti AR, Fleming GJ (2012). Cuspal deflection and microleakage in premolar teeth restored with bulk-fill flowable resin-based composite base materials. J Dent 40:500-505.

Moraes RR, Gonçalve LS, Ogliari FA, Piva E, Sinhoreti MA, Correr-Sobrinho L (2008). Development of dental resin luting agents based onBis-EMA4: bond strength evaluation. Express Polym Lett 2:88-92.

Opdam NJM, Roeters FJM, Feilzer AJ, Verdonschot EH (1998). Marginal integrity and postoperative sensitivity in class 2 resin composite restorations in vivo. J Dent 26:555-562.

Ozer S, Sen Tunc E, Gonulol N (2014). Bond strengths of silorane- and methacrylate-based composites to various underlying materials. Biomed Res Int 1-6.

Park MG, Ro JH, Park JK, Ko CC, Kwon YH (2013). Effect of a DPSS laser on the shear bond strength of ceramic brackets with different base designs. Lasers Med Sci 28:1461-1466.

Park J, Chang J, Ferracane J, Lee IB (2008). How should composite be layered to reduce shrinkage stress: incremental or bulk filling ? Dent Mater 24:1501-1505.

Primus CM, Chu CC, Shelby JE, Buldrini E, Heckle CE (2002). Opalescence of dental porcelain enamels. Quintessence Int 33:439-449.

Sakaguchi RL, Douglas WH, Peters MC (1992). Curing light performance and polymerization of composite restorative materials. J Dent 20:183-188.

Shortall AC, Palin WM, Burtscher P (2008). Refractive index mismatch and monomer reactivity influence composite curing depth. J Dent Res 87:84-88.

Taneja S, Kumar P, Kumar A (2016). Comparative evaluation of the microtensile bond strength of bulk fill and low shrinkage composite for different depths of Class II cavities with the cervical margin in cementum: An in vitro study. J Conserv Dent 19:532-535.

Versluis A, Douglas WH, Cross M, Sakaguchi RL (1996). Does an incremental filling technique reduce polymerization shrinkage stresses ? J Dent Res 75: 871-878.

Zorzin J, Maier E, Harre S, Fey T, Belli R, Lohbauer U, Petschelt A, Taschner M (2015). Bulk-fill resin composites: polymerization properties and extended light curing. Dent Mater 31:293-301.

ABSTRACT

Evaluation of bulk-fill resin composite on the shear bond strength of metal brackets

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This study evaluated the shear bond strength (SBS) and adhesive remnant index (ARI) of bulk-fill resin composites compared to conventional bonding adhesive. One hundred and eighty human teeth were randomly divided into four different adhesive groups: (1) Filtek Bulk Fill, (2) Tetric-N Ceram Bulk Fill, (3) SonicFill, and (4) Transbond XT. These groups were divided into three subgroups by light-curing units (LCU). Orthodontic metal brackets were bonded to the enamel surface using the four different adhesives, and light curing was performed. After specimens were stored for 24 h in distilled water, SBS was measured. Adhesive remnant index (ARI) scores were determined after the failure of orthodontic brackets. For all LCUs, Transbond XT had a higher SBS than bulk-fill resin composites. For all LCUs, the bulk-fill resin composites showed clinically acceptable SBS values. Analysis of variance revealed significant differences between the bulk-fill resin composite groups, with SonicFill having a significantly higher SBS than the other two bulk-fill resin composites ($p < 0.05$). However, the LCUs had no significant impact on SBS ($p = 0.061$). ARI scores were significantly different among adhesive groups, but ARI scores were not significantly different among LCUs. The SBS of all bulk-fill resin composites was the higher than the recommended SBS of the adhesives (5.9 - 7.8 MPa). In the Filtek Bulk Fill and Tetric-N Ceram groups that showed the lower SBS values, more adhesive remained on the enamel surface. Bulk-fill resin composites can be used clinically as adhesives for orthodontic bracket bonding.

Key Words: Bulk-fill resin composite, shear bond strength, adhesive, metal bracket