Original Article

Comparison of Shear Bond Strength of Composite to Stainless Steel Crowns Using Two Mechanical Surface Treatments and Two Bonding Systems

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Abstract

Objectives: This study aimed to compare the shear bond strength (SBS) of composite to stainless steel crowns (SSC) using two mechanical surface treatments (MSTs) and two bonding systems.

Materials and Methods: Eighty-four SSCs were divided into six groups of 14; Group1: No MST+Scotchbond Universal adhesive (N+U), Group 2: Surface roughening by a diamond bur+Scotchbond Universal adhesive (R+U), Group 3: Sandblasting+Scotchbond Universal adhesive (S+U), Group 4: No MST+Alloy Primer+Clearfil SE Primer and Bond (N+A), Group 5: Surface roughening by a diamond bur+Alloy Primer+Clearfil SE Primer and Bond (R+A), Group 6: Sandblasting+Alloy Primer+Clearfil SE Primer and Bond (S+A). After MST and bonding procedure, composite cylinders were bonded to the lingual surface of SSCs, then the SBS of composite to SSCs was measured using a universal testing machine following thermocycling.

Results: The SBS of groups R+U and S+U was significantly higher than that of group N+U. No significant difference was noted in SBS of groups R+U and S+U. The SBS of group S+A was significantly higher than that of groups N+A and R+A. No significant difference was noted in the SBS of groups N+A and R+A ($P>0.05$).

Conclusions: In Scotchbond Universal adhesive groups, sandblasting and surface roughening by diamond bur significantly increased the SBS of composite to SSCs compared to no MST. In Alloy Primer groups, sandblasting significantly increased the SBS of composite to SSC compared to surface roughening with diamond bur and no MST.

Keywords: Tooth, Deciduous; Crowns; Composite Resins; Shear Strength

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INTRODUCTION

Stainless steel crowns are the most commonly used treatment modality for full-coverage restoration of primary molar teeth. American Academy of Pediatric Dentistry recommends stainless steel crowns (SSC) treatment for cases with extensive and multi-surface caries. Despite many advantages, the metal appearance of these crowns is unpleasant to the parents and children and they prefer tooth-colored restorations to silver-colored fillings regardless of location of restorations [1-3]. Considering the increasing demand for esthetic restorations, several treatment options have been proposed for primary teeth to overcome this shortcoming such as open face SSCs (OFSSCs), strip crowns, pre-veneered SSCs (PVSSCs) and zirconia crowns [2]. The OFSSCs benefit from the durability of SSCs while having an esthetic appearance [2]. However, their facing may detach and the metal margin around composite in this type of restoration may have an unpleasant appearance [4,5]. Strip crowns are esthetic but have the highest technique sensitivity among all treatment options [6]. They need a clean, dry surface and sufficient tooth structure in order to have retention [2]. In PVSSCs, addition of an esthetic facing has increased the thickness of these crowns. Consequently, they are more difficult to crimp and fit compared to SSCs [7] and require greater tooth preparation [6]. Susceptibility to fracture, chipping and separation of the veneer and high cost are among other disadvantages of these crowns [6,7].

Zirconia crowns are the most recent type of esthetic crowns for primary teeth [8]. They highly resemble tooth color and have very high fracture toughness and biocompatibility. However, high cost, greater thickness than SSCs and inability to crimp are among the drawbacks of these crowns [9].

Considering these shortcomings, attempts have been made to find a more esthetic method with the advantages of SSCs. Chair-side veneering of well-adjusted SSCs using composite (first defined by Weildenfield et al, [10] in 1995) can be a suitable approach to achieve esthetic goals in addition to durability and strength, given that a durable bond is obtained. Mechanical and chemical methods are used to enhance composite resin bond to metals.

In this study, we roughened the surface of SSCs by diamond bur and sandblasting (mechanical methods) and then used two bonding systems (chemical methods). This study aimed to compare the SBS of composite to SSCs using two methods of mechanical surface treatments (MST) and two different bonding systems.

MATERIALS AND METHODS

In this in vitro study, 84 pre-crimped pre-contoured SSCs (3M ESPE, St. Paul, MN, USA) of primary mandibular left second molar (size 5) were divided into six groups of 14 SSCs based on the type of MST and bonding system (Table 1).

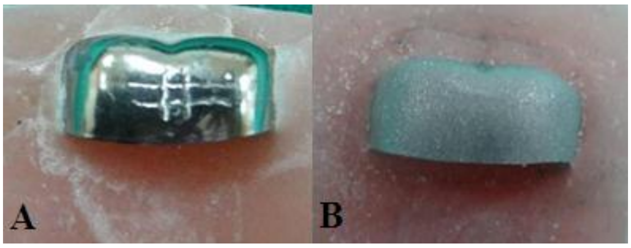

Fig. 1: SSC surface; (A) after roughening by diamond bur, (B) after sandblasting

The SSCs were mounted in cubic acrylic molds measuring 7×20×30 mm in such a way that the lingual surface of crowns was completely accessible for bond to composite.

The two types of MST in this study were performed as follows:

Surface roughening using a diamond bur

Using a ¼ round diamond bur, two vertical and two horizontal grooves were created on the lingual surface of SSCs. The grooves were 4mm long and had 1mm distance from one another (Fig. 1A).

Sandblasting

For sandblasting of the surface of SSCs, 50μm aluminum oxide particles were used for 20 seconds in such a way that the lingual surface of SSCs was completely sandblasted (Fig. 1B). After MST, specimens were etched with 9.6% hydrofluoric (HF) acid for 20 seconds. By doing so, the metal surface was cleansed. Specimens were then rinsed and dried. Next, the following two bonding systems along with the composite resins recommended by the manufacturers were applied:

1- Scotchbond Universal adhesive (Scotchbond™ Universal adhesive, 3M ESPE, Seefeld, Germany).

Table 1: Descriptive data of different groups based on the type of MST and bonding system

Group	Abbreviation	Mechanical surface treatment (MST)	Bonding agent	Type of composite
1	N+U	No MST	Universal Scotch Bond	ZX250
2	R+U	Surface roughening by diamond bur	Universal Scotch Bond	ZX250
3	S+U	Sandblasting	Universal Scotch Bond	ZX250
4	N+A	No MST	Alloy Primer+Clearfil SE Bond	Clearfil AP-X
5	R+A	Surface roughening by diamond bur	Alloy Primer+Clearfil SE Bond	Clearfil AP-X
6	S+A	Sandblasting	Alloy Primer+Clearfil SE Bond	Clearfil AP-X

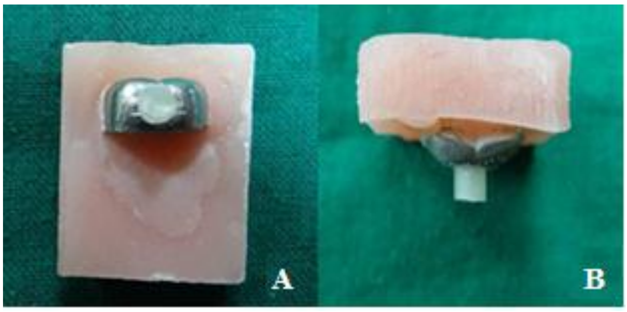

Fig. 2: Composite bonded to the SSC surface: (A) Frontal view, (B) Superior view

2- Alloy Primer (Kuraray, Okayama, Japan) plus Clearfil SE Primer and Bond (Kuraray, Okayama, Japan)

Scotchbond Universal adhesive application

According to the manufacturer's instructions, the bonding agent was applied to the SSC surface using a micro-brush; 10 seconds time was allowed and after gentle air spray, it was cured for 15 seconds. Next, Filtek Z250 composite resin (3M ESPE, St. Paul, MN, USA) was applied to a transparent prefabricated cylindrical mold (measuring 3×3mm). The mold was positioned at the center of the lingual surface of SSCs. The composite was condensed and light cured for 40 seconds using a light curing unit (Fig. 2).

Alloy Primer application

According to the manufacturer's instructions, Alloy Primer was applied to the lingual surface of SSCs using a micro-brush. After 10 seconds of waiting, it was gently air sprayed. Next, the primer of Clearfil SE Bond was applied and after 10 seconds of waiting, it was gently air-dried. Finally, the bonding agent of Clearfil SE Bond was applied and after 10 seconds of waiting, it was gently air-dried and light cured for 15 seconds. Clearfil AP-X composite (Kuraray, Okayama, Japan) was then applied to a prefabricated cylindrical mold (measuring 3mm in diameter and 3mm in height). The mold was positioned at the center of the lingual surface of SSCs and after condensing the composite, it was cured for 40 seconds. After preparation of all six groups, the specimens were subjected to thermocycling for 1500 cycles between 5-55°C (each cycle for 30 seconds). Then, the SBS of specimens was measured using a universal testing machine (Zwick Roell, Ulm, Germany) in Newton (N). Shear load was applied by a blade to the composite-SSC interface at a crosshead speed of 0.5mm/min until fracture. The load at fracture in N was converted to Megapascals (MPa) by dividing it by the surface area (Fig. 3). The mode of failure in all specimens was determined by two calibrated observers blinded to the group allocation of specimens using a×5 magnifier and classified into adhesive, cohesive and mixed types.

Statistical analysis

The data were analyzed using SPSS version 21. The mean and standard deviation (SD) of SBS was reported for the six groups. Two-way ANOVA was used to assess the effect of MST and type of bonding system on the SBS. Considering the significant interaction effect of the above-mentioned two factors ($P<0.001$), comparison of the means was performed separately for each factor. T-test was applied to compare bonding systems in each MST group while one-way ANOVA was used for the comparison of mean SBS values with each method of MST separately for each bonding system. For pairwise comparison of groups after applying ANOVA, Tukey's test or Dunnett's T3 test was used depending on the homogeneity or non-homogeneity of variances.

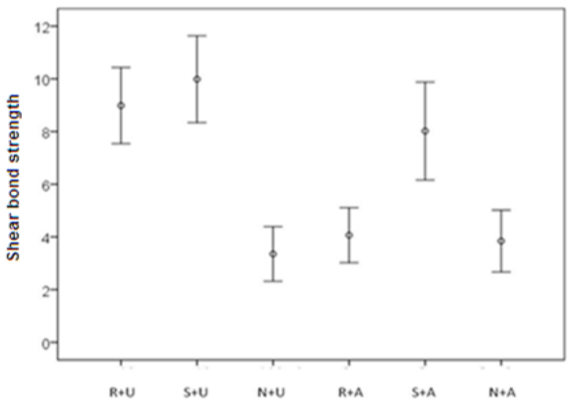

Fig. 3: The mean shear bond strength of the six groups in MPa along with 95% CI

Table 2: Shear bond strength of composite resin to SSCs in the six groups in MPa and comparison of the two bonding systems used based on the method of MST

Mechanical surface treatment	Bonding agent	Mean ± standard deviation (MPa)	P-value
No MST	Universal Scotchbond	3.34±1.72	0.507
	Alloy Primer	3.83±2.04	
Surface roughening by diamond bur	Universal Scotchbond	8.99±2.38	<0.001
	Alloy Primer	4.07±1.79	
Sandblasting	Universal Scotchbond	9.99±2.59	0.103
	Alloy Primer	8.02±3.21	

The mode of failure was compared among the groups using chi square test. P<0.05 was considered statistically significant.

RESULTS

Based on the results, no significant difference (P=0.503) was found in SBS of the two bonding systems between the two groups of MSTs (groups N+U and N+A). In groups R+U and R+A (MST with a round diamond bur), a significant difference was noted in SBS between the two bonding systems and the mean SBS in group R+U was significantly higher than that in group R+A (P<0.001).
In groups S+U and S+A (MST with sand-blasting), no significant difference (P=0.103) was noted in SBS between the two bonding systems (Table 2). Comparison of MST methods based on the type of bonding system revealed that groups N+U, R+U and S+U (using Scotchbond Universal adhesive with different MSTs) were significantly different (P<0.001) in terms of SBS (Table 3).
Groups N+A, R+A and S+A (using Alloy Primer with different MSTs) were also significantly different (P<0.001) in terms of SBS (Table 3).
Pairwise comparison of groups in terms of SBS based on the type of bonding system used revealed significant differences in SBS of groups N+U and R+U and also N+U and S+U (P<0.001).
Based on Table 4, a significant difference was noted in the mean SBS of groups R+A and S+A (P=0.02). Pairwise comparison of groups S+A and N+A revealed a significant difference in SBS (P=0.01). Pairwise comparison of other groups revealed no significant difference (Table 4). The mode of failure was significantly different among the six groups.
Adhesive fracture was the most frequent in groups N+U and N+A while mixed fracture was the most common in groups R+U and S+U. The frequency distribution of mode of failure in groups R+A and S+A was not significantly

Table 3: Comparison of shear bond strength of the six groups (MPa) based on the type of bonding system used

Bonding agent	Mechanical surface treatment	P-value
Alloy Primer+Clearfil SE Bond	N+A/R+A/S+A	<0.001
Universal Scotchbond	N+U/R+U/S+U	<0.001

Table 4: Pairwise comparison of shear bond strength of the six groups (MPa) based on the type of bonding system used

Group 1	Group 2	P-value
N+U	R+U	<0.001
N+U	S+U	<0.001
R+A	S+A	0.02
N+A	S+A	0.001
R+U	S+U	0.516
R+A	N+A	0.986

Table 5: The frequency distribution of mode of failure in the six groups

Group	Mode of failure	
	Mixed	**Adhesive**
N+U	8.3%	91.7%
R+U	61.5%	38.5%
S+U	61.5%	38.5%
N+A	14.3%	85.7%
R+A	42.9%	57.1%
S+A	42.9%	57.1%

different from that in groups R+U and S+U and also N+U and N+A (Table 5).

DISCUSSION

Most previous studies have evaluated the effect of MSTs or chemical methods on SBS. However, we evaluated the interaction effect of two MSTs and two bonding systems on the SBS of composite to SSCs. The manufacturers of the two bonding systems used in this study claim that these systems provide adequate resin-metal bond. Based on the results, the highest SBS was obtained in S+U group (9.99±2.59 MPa) while the lowest value was obtained in N+U group (3.34±1.72 MPa). Considering the significant interaction effect of MST and type of bonding system on SBS, the results are discussed separately for each factor.

Mechanical surface treatment

Different mechanical methods have been used to enhance composite bond to metal such as sandblasting [11,12], surface roughening by diamond bur [13,14], air abrasion [15], ultra-violet radiation [16] and spot welding [17]. Sandblasting is one method to provide mechanical retention. Some studies have shown that sandblasting increases the composite bond to SSCs [1]. In the process of sandblasting, a specific boundary cannot be outlined for sandblasting and particles may be propelled beyond the surface area specified for veneering. This may result in greater entrapment and accumulation of microorganisms [18]. Thus, aside from sandblasting, surface roughening by diamond bur was also evaluated in the current study as an affordable, easy to perform MST and the result was compared with that of sandblasting. Based on the results, in groups without MST, no significant difference was noted between the two bonding systems. Also, the SBS values were the lowest in N+U and N+A groups. The low SBS values obtained in these two groups were probably attributed to the lack of MST and application of bonding agents to a completely smooth surface with no mechanical retention/interlocking. Also, the SBS of groups that were sandblasted was not significantly different from that of other groups. However, the sandblasted groups still had the highest SBS. This finding indicates increased SBS due to creation of a rough surface and increased surface area by sandblasting. In groups where surface roughening was performed by a diamond bur, the SBS was significantly different between the two bonding systems and the SBS in R+U group was higher than that in R+A group. It appears that surface roughening by diamond bur improves the SBS when Scotchbond Universal adhesive is used. But, this was not the case for Alloy Primer. The reason may be that in Alloy Primer bonding system, primers and the bonding agent are applied in three steps and the degree of roughness created by diamond bur may not be sufficient for this purpose; whereas, Scotchbond Universal adhesive is applied in one step. In groups where sandblasting was performed for MST, no significant difference was noted in SBS and this value was 9.99±2.59 MPa in group S+U and 8.02±3.21 MPa in group S+A. It appears that in both groups, sandblasting increased the SBS by creating a rough surface and increasing the surface area. Hattan et al, [1] in their study used sandblasting for MST and reported higher SBS of composite to SSCs in Scotchbond Universal adhesive group compared to Adper and Prime & Bond NT groups; this result was in accordance with our finding. The manufacturer of Adper and

Prime & Bond NT do not claim an optimal bond to metal. Also, the values obtained in their study were higher than our obtained values (17.62±4.22 MPa) and the reason may be conduction of thermocycling with lower number of thermal cycles in their study (500 thermal cycles in their study versus 1500 cycles in ours).

Bonding system

Both Alloy Primer and Scotchbond Universal adhesive used in the current study have MDP monomer in their composition. Presence of MDP monomer along with silane in the composition of bonding agent increases the bond strength of resin to metal, alumina, zirconia and ceramic. This characteristic enables intraoral repair of damaged indirect restorations. MDP monomer chemically bonds to non-precious metals from its phosphoric acid group end; while, the double bond in the other end of the molecule is copolymerized with resin monomers [19,20].

Based on our results, the highest SBS belonged to S+U group while the lowest was observed in N+S group. In groups where Universal Scotch Bond was used as the bonding agent, significant differences were noted in SBS among different MSTs and the SBS in S+ U and R+U groups was significantly higher than that in N+U group. The difference in SBS between S+U and R+U groups was not statistically significant. It appears that both MSTs can adequately enhance the SBS probably by increasing the surface area and creating a macro-retentive surface. In groups where Alloy Primer was used for bonding, significant differences were noted in SBS among groups with different MSTs and S+A group had significantly higher SBS than R+A and N+A groups. Moreover, no significant difference was found in groups N+A and R+A. The difference between sandblasting and surface roughening by diamond bur may be due to the different surface area receiving the MST. In the sandblasting method, the entire surface area of the interface between the SSC and composite is sandblasted by aluminum oxide particles. But, in surface roughening by diamond bur, surface roughening is performed in only a portion of the surface area. Considering the fact that roughening by bur did not result in a significant improvement in SBS compared to no MST group for this specific bonding agent, it appears that sandblasting in conjunction with the application of Alloy Primer is the method of choice for achieving a higher SBS of composite to SSCs. Salama and el-Mallakh [17] reported that sandblasting provided higher SBS compared to no MST in bond of compomer to SSCs (9.51±2.47 versus 2.99± 1.38); this finding was similar to our result. Although they did not perform thermocycling, they obtained SBS values close to ours for Scotchbond Multi Purpose Plus TM (9.37±3.7) and Dyract PSA Prime/Adhesive (9.52±2.46) [17].

Al-Shalan et al, [21] found no significant difference in SBS of composite to SSCs between surface roughening by bur and no MST. They used five different bonding systems in their study. Also, they roughened the surface using #4 round diamond bur. Their results were similar to our findings regarding surface roughening by bur followed by the application of Alloy Primer. But, the results of the two studies were different for surface roughening followed by the application of Scotchbond Universal adhesive. This difference may be explained by the different bonding systems used or the technique of surface roughening. Ajami et al, [22] found no significant difference in SBS of composite to SSCs using (A) Single Bond, (B) All Bond and (C) Panavia F2 and three methods of surface preparation namely acidic gel, sandblasting and surface roughening by fissure bur. No difference was reported in SBS between surface roughening by bur and sandblasting and this result is in line with our findings in groups where Scotchbond Universal adhesive was used. However, our findings in Alloy Primer groups were not in accordance with those of Ajami et al, [22].

In our study, significant differences existed among groups in terms of mode of failure. Most fractures were of adhesive type in N+U and N+A groups; whereas, in S+U and R+U groups, mixed fractures had a higher frequency.

In groups S+A and R+A, most fractures were of adhesive type. No cohesive fracture occurred in our specimens. In the study by Hattan et al, [1] most fractures were of adhesive type; which is in line with our results. But, they also reported cohesive fractures, which is in contrast to our study. This difference may be due to errors in observation or variable definitions of cohesive fractures. Many previous studies have reported the SBS of bonding systems to dentin to be in the range of 10-12 MPa. Moreover, the minimum required clinical bond strength for bracket bonding to permanent teeth has reported to be 6-8 MPa [23].

Based on our results, S+U, S+A and R+U provide adequate bond strength. Also, considering the single step application of Scotchbond Universal adhesive compared to the three-step Alloy Primer and also higher SBS values obtained in the Scotchbond Universal adhesive groups, Scotchbond Universal adhesive seems to be a more suitable bonding system for bonding of composite to SSCs. Since both surface roughening by bur and sandblasting followed by Scotchbond Universal adhesive application yielded high SBS values, the authors believe that both methods of MSTs are suitable for bond enhancement. Considering the lack of a significant difference between the two methods of MST and lower cost of surface roughening by diamond bur compared to sandblasting, surface roughening by diamond bur may be preferred to sandblasting in the clinical setting. Chair-side bonding of composite to SSCs not only improves their esthetic appearance, but also can be used for repair of PVSSCs. Moreover, it enables the use of SSC for an abutment tooth in splinting. However, addition of composite to SSC increases the treatment time [10]. Last but not least, it should be noted that this study had an in-vitro design and this indicates the need for future in vivo studies to assess the validity of the clinical application of these techniques and the durability of composite bond to SSCs using these methods.

CONCLUSION

1. With the use of Alloy Primer, sandblasting provided higher SBS of composite to SSCs compared to no MST and roughening by diamond bur.
2. With the use of Scotchbond Universal adhesive, both sandblasting and surface roughening by bur provided higher SBS of composite to SSCs compared to no MST.
3. Both Scotchbond Universal adhesive and Alloy Primer in conjunction with sandblasting provided adequate SBS of composite to SSCs.

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