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ORTHODONTIC BRACKET BONDING PERFORMANCE: ASSESSING THE ROLE OF TEMPORARY CROWN MATERIALS AND SURFACE TREATMENT TECHNIQUES

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Abstract
In the contemporary digital age, there is a steady rise in the number of adults seeking orthodontic treatment for both esthetic enhancements and oral rehabilitation. Adult patients often present with unique challenges, including missing teeth, multiple restorations, and artificial prosthesis. Typically, final restorations are deferred until the completion of orthodontic treatment, necessitating the bonding of brackets to provisional crowns throughout the orthodontic journey. This practice, however, poses distinct challenges, as studies have indicated that bonding brackets to provisional crowns is more intricate compared to bonding to natural teeth. Furthermore, the provisional crown material must exhibit exceptional physical and mechanical properties, withstand occlusal and orthodontic forces, offer superior handling, boast enhanced esthetics, and demonstrate biocompatibility with oro-dental tissues.

This article delves into the various aspects of orthodontic bracket bonding on provisional crowns made from diverse materials. We explore the importance of selecting the appropriate provisional crown material and its impact on the overall success of orthodontic treatment. In addition, we discuss the challenges associated with direct bracket bonding on different provisional crown materials and the critical role of surface treatment in improving bond strength. Our review encompasses traditional materials like polycarbonate and auto-polymerizing polymethylmethacrylate (PMMA) resins, as well as innovative materials such as computer-aided design/computer-aided

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manufacturing (CAD/CAM) PMMA and bis-acryl resins for provisional crown fabrication.

INTRODUCTION

In this new-age digital era, the number of adults seeking orthodontic treatment for better esthetics and oral rehabilitation is continuously increasing. Adult patients are often associated with missing teeth, multiple restorations and artificial prosthesis. Final restoration for any patient is mostly deferred until the completion of orthodontic treatment.[1-2] This situation requires the orthodontist to bond brackets to provisional crowns and restoration for the complete duration of orthodontic treatment. Studies have shown than bonding brackets to provisional crown is more difficult than natural teeth.[3-4] Incidentally, the provisional crown material on which the bracket has been bonded should have superior physical and mechanical properties, be able resistant to occlusal and orthodontic forces. Moreover, they should have better handling, enhanced esthetics and biocompatibility with oro-dental tissues.[3,5]

The interim or provisional crown can be prefabricated or custom made from different types of material. Crowns are usually made with the traditional polycarbonate and auto-polymerizing polymethylmethacrylate (PMMA) resins. Certain new class of materials such as computer aided design/ computer aided manufacturing (CAD/CAM) PMMA material and bis-acryl resins have also been employed recently to fabricate provisional crowns.

Bonding orthodontic brackets on these provisional crowns made from different material is a critical step in orthodontic treatment.[6] Direct bonding of brackets on these crowns lead to very poor bond strength and hence some kind of surface treatment is required to improve the bond strength of these brackets.

Various types of surface treatment methods such as roughening, grinding, sandblasting, application of chemical agents and lasers have been used to establish a strong bond of adhesive to provisional crown.[7-10] A clinically acceptable bond strength of 6-8MPa is recommended so as the bracket is bonded strong enough to not get debonded easily whereas not so strong to allow smooth debonding without damaging the crown
surface.11-12

Various studies have been done in the past to evaluate the shear bond strength (SBS) of the orthodontic brackets on various provisional crown material subjected to different surface treatment methods. However, limited studies and investigations have been done to examine the novel, new class material such as CAD/CAM PMMA crowns, bis-acryl resins and latest surface treatment methods like CO_2 laser. Hence the aim of this study is to evaluate the SBS of orthodontic brackets to three different types of provisional crown material like auto-curing PMMA, CAD/CAM PMMA and bis-acryl resin treated with four different type of surface treatment methods such as surface roughening, sandblasting, MMA chemical application and CO_2 laser.

MATERIALS AND METHODS Materials

In this in-vitro study conducted in Najran University, Saudi Arabia, a total of 240 provisional crowns were fabricated from three different type of provisional material (n=80 for each group). Auto-polymerizing PMMA in powder and liquid form (DPI self-cure tooth molding powder, DPI), CAD/CAM PMMA blocks (Telio CAD, Ivoclar Vivadent, Schaan, Liechtenstein) and bis-acryl in cartridge with dispensing guns and mixing tips (Protemp 4 temporization material, 3M ESPE, Germany) were used in this study. All the materials were mixed according to the manufacturer's instructions and poured into the mold. Once the material was set, it was removed and stored for 24 hours to allow complete polymerization of the material. The blocks were cut in standard size of 4mm x 8 mm using a dental lathe machine. The blocks were then respectively polished with 200-, 500- and 1000-grit silicon carbide paper disc for 20 seconds each (Figure 1).

Methods

All the 240 samples were randomly and equally divided into 3 groups of different provisional crown material. Further 80 samples of each provisional material were randomly divided into 4 subgroups of various surface treatment methods comprising of 20 samples in each subgroup. Each 20 samples of the three provisional crown materials were subjected to the following surface treatment methods. First method involved roughening the surface using greenstone (Dura-Green, Shofu Dental GmbH, Germany) with lowspeed hand piece at constant pressure for 10 seconds at 2000 rpm. Second method involved sandblasting the surface with 50 µm aluminum oxide particles from a distance of 10 mm for 5 seconds under a pressure of 50 pound-force per square inch (Microetcher sandblasting, Z ZSmile Dental Store, China). Third method involved conditioning with methylmethacrylate (MMA) (DPI RR cold cure monomer, DPI) on the surface of the blocks. The fourth surface treatment method comprised of CO_2 laser (Smart US-20D, Deka, Italy) in super pulse mode with power output of 1 W, frequency of 2 Hz at a distance of 12.5 mm for 15 ms.

After this, all the block samples were cleaned with deionized water for 1 minute and subsequently dried with oil-free air to remove any possible dirt or oil from the surface. The surfaces were then etched with 37% phosphoric acid (Scotchbond, 3M ESPE, Germany) for 30 seconds and cleaned with air-water spray for 15 seconds and then dried with oil-free air blasting for 15 seconds. An adhesive primer (Transbond XT, 3M Unitek, Monrovia, Calif, USA) was applied on the etched surface where the bracket was to be bonded. Molar tubes of APC II adhesive coated brackets (3M Unitek, Monrovia, Calif, USA) of 0.022" MBT prescription were bonded to the surface using light-cure unit (Bluephase Style 20i, IvoclarVivadent, Schaan, Liechtenstein) as per the manufacturer's instructions (Figure 2, 3 and 4). A uniform force was applied while positioning the bracket, the excess adhesive was removed with a probe and the bracket was cured for 10 seconds on each side for a total of 40 seconds. (Figure 5) In order to standardize the steps, the process of block preparation, surface treatment and bracket bonding were performed by a single operator for all the blocks.

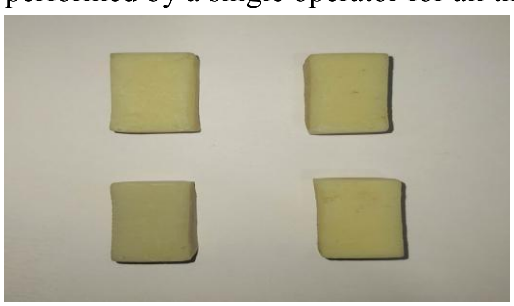

Fig.1: Blocks fabricated and polished from different provisional crown material

Fig. 2: Molar tubes of APC II adhesive coated brackets, bracket placement tweezer and block used in this study

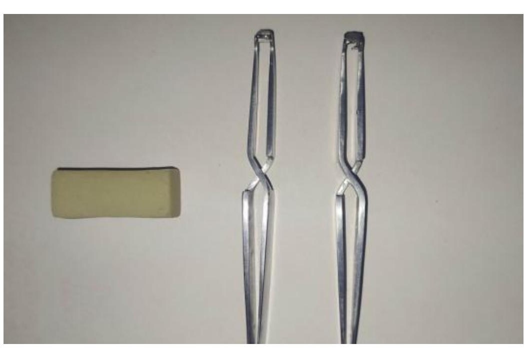

Fig. 3: Adhesive precoated bracket and acid-etched block used in this study

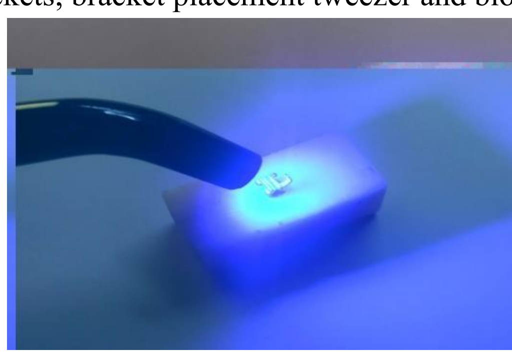

Fig. 4: Light curing of the APC II adhesive coated bracket on the block surface

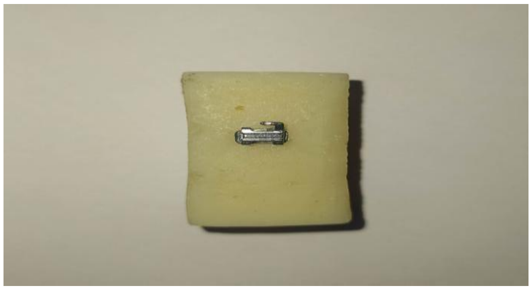

Fig. 5: Bracket bonded on the surface treated block ready for SBS testing**.**

Shear Bond Strength Test

The samples were then subjected to SBS test on a Universal Testing Machine with a cross-head speed of 0.5 mm per minute. The stress was applied on the occluso-gingival direction until failure or bond rupture. The strength value was obtained in Newton and later converted into megapascals (MPa). Each sample was then analyzed under a microscope with 16X magnification. The Adhesive Remnant Index (ARI) score as described by Årtun and Bergland [13] was used to evaluate the mode of bond failure. The amount of residual adhesive left on the debonded bracket was recorded as followed using the ARI score:

0: no adhesive remnant (0%) on specimen (provisional crown/tooth), 100% on bracket

1: less than half (<50%) of the adhesive remnant on the specimen, >50% on bracket

2: more than half (>50%) of the adhesive remnant on the specimen, <50% on bracket

3: 100% adhesive remnant on specimen, none (0%) on bracket

Statistical Analysis

The data was collected and analyzed using SPSS version 11 (SPSS INC., Chicago, IL, USA). Twoway analysis of variance (ANOVA) was used to analyze the SBS values of different provisional material and surface treatment methods. Multiple comparisons were done using Tukey's HSD post-hoc tests. Chi-square test was used to determine the differences between the ARI score and conditioning methods. A p-value of <0.05 was considered to be statistically significant.

RESULTS

Table 1 describes the mean and standard deviation of SBS for each material and surface treatment methods. The mean SBS was highest in the bis-acryl group (16.08 ± 3.54 MPa) and lowest in the autopolymerizing PMMA group (9.41 ± 3.05 MPa). The two-way ANOVA demonstrated statistically significant differences ($p<0.05$) in the mean SBS values of different surface treatment methods.

The post-hoc Tukey's test demonstrated that sandblasted and CO_2 laser sub-groups showed significant differences ($p<0.05$) in the CAD/CAM PMMA group. In the bis-acryl group, sandblasted subgroup showed statistically significant differences with the other groups ($p<0.05$). When comparing different material with each other, no significant differences were found in their mean SBS values.

Table 1: SBS mean and SD values of different materials and surface treatment methods (values in MPa).

Material	**Surface Treatment**				**pvalue^{X}**
	SBS Mean ± SD				
	Surface Roughening	**Sandblasting**	**Chemical Conditioning**	**CO_2 laser**	
Auto-polymerizing PMMA	10.42 ± 2.54^{a}	9.41 ± 3.05^{a}	11.41 ± 3.56^{a}	12.56 ± 3.22^{a}	0.062

CAD/CAM PMMA blocks	11.89 ± 2.18^{a}	11.65 ± 4.01^{b}	12.92 ± 3.11^{a}	13.29 ± 3.98^{c}	0.082
bis-acryl	14.16 ± 2.97^{a}	14.88 ± 3.45^{b}	15.77 ± 2.84^{a}	16.08 ± 3.54^{a}	0.056
p-Value*	<0.001	<0.001	<0.001	<0.001	

^{X}Using Two-way ANOVA test

Different alphabets in the superscript indicate statistically significant difference between groups (Tukey's test, $\alpha = 0.05$).

Table 2 describes the ARI score after SBS test of each group and sub-group. Chi-square test demonstrated no significant difference in the ARI scores of different materials and surface treatment methods. However, it was observed that the ARI scores 2 and 3 were predominantly more in the bis-acryl groups whereas the other groups consisted more of ARI score 0 and 1.

Table 2: ARI scores of different materials subjected to various treatment methods.

Material	**Surface Treatment**	**ARI Score n (%)**				p-value
		Score 0	Score 1	Score 2	Score 3	
Auto-polymerizing PMMA	Surface Roughening	17	2	1	0	0.0875
	Sandblasting	16	3	1	0	
	Chemical Conditioning	18	1	1	0	
	CO_2 laser	17	2	1	0	
CAD/CAM PMMA blocks	Surface Roughening	18	1	1	0	0.0651
	Sandblasting	17	1	1	1	
	Chemical Conditioning	17	2	1	0	
	CO_2 laser	16	3	1	0	
bis-acryl	Surface Roughening	14	2	3	1	0.0532
	Sandblasting	13	3	2	2	
	Chemical Conditioning	15	2	2	1	
	CO_2 laser	15	3	1	1	

DISCUSSION

This study was conducted in Najran University, Saudi Arabia to evaluate the shear bond strength of orthodontic brackets, bonded to three different types of provisional crown material like auto-curing PMMA, CAD/CAM PMMA and bis-acryl resin treated with four different type of surface treatment methods such as surface roughening, sandblasting, MMA chemical application and CO_2 laser. In this study it has been found that none of the surface treatment methods leads to significantly better SBS in the auto-polymerizing PMMA provisional material. The findings of this study are in accordance with the findings of Almeida et al.,[7] Chay et al.,[14] and Najafi et al.,[15] who concluded no significant difference in bond strength between various surface treatment methods on PMMA blocks or resin restorations. Also in this study, CAD/CAM PMMA provisional material has shown better SBS when treated with sandblasting and CO_2 laser compared to other treatment methods. This finding is in contrast to the reporting of Graces et al.,[16] who found that the CAD/CAM PMMA material had lower than optimum strength for bonding brackets.

Lastly in the bis-acryl group in this study, sandblasting the surface has shown to increase the SBS in comparison with other methods. Also, the mean SBS was highest in the bis-acryl group (16.08 ± 3.54 MPa) for the complete sample in this study.

These findings regarding bis-acryl provisional material are similar to the findings of Chay et al.,[14] Graces et al.,[16] and Maryanchik et al.[17] who found that when bis-acryl provisional material were sandblasted, it produced better SBS values than other material and surface treatment methods.

The variation in the different bond strength of various materials can be attributed to their physical and chemical properties. Moreover, the surface treatment methods produce certain effects in the microstructure level, which alter the chemical bonding between the adhesive and provisional material. On a molecular level, PMMA is a long chain single polymer with numerous carbon-carbon double bonds which are potential binding sites for the adhesive resin. Chemical application of MMA over PMMA leads to swelling and softening of the surface. This might create some retentive areas for the adhesive to bind but might also be the reason of inferior bond strength.[18-19] According to Chung et al.,[20] wetting the surface only with monomer will not increase the adhesive resistance; hence, additional or other methods are preferred. Sandblasting the surface of PMMA creates micro-porosities which increases the bonding area and thereby enhances the bond strength. Similarly, application of CO_2 laser on PMMA surfaces leads to creation of honey-comb patterned deep craters which again aids in promoting a strong bond between the PMMA and adhesive resin or bonding material.[21-22] Hence in this study, sandblasting and CO_2 laser application on PMMA blocks have shown better mean SBS than other surface treatment methods. Also, CAD/CAM manufactured PMMA blocks are less prone to shrinkage intra-orally as it occurs during the processing of the blocks externally. These materials also present with high fracture strength and low marginal gap thereby making them good choices for provisional crown material.[16,23]

In this study, bis-acryl resin materials have exhibited the maximum mean SBS throughout the sample. These are new-class of material which produces better strength, marginal adaptation and low exothermic reaction during setting when compared to PMMA resins. The bifunctional acrylates in the bis-acryl provides extra bonding sites and numerous cross-links which increase their mechanical attachment and increases the bond strength.[3,19] Sandblasting the surface of bis-acryl provisional material has shown to increase the shear bond strength as compared to other treatment methods. This can be explained by the fact that sandblasting creates more damaged surface of the material, thereby increasing its mechanical and chemical bond value.[7,14] This drawback can be ignored since the crown will be used for a provisional period followed by a final prosthesis.

In this study, ARI scores were used to study the mode of bond failure. Statistically, the mode of failure was independent of the various surface treatment methods with none of the methods exhibiting superiority over others. Most of the material presented with adhesive type failure with the brackets debonding at the crown-adhesive interface, i.e., Score 0 and 1. This demonstrates a strong adhesion value between the bracket and the adhesive. Similar findings were reported by Chay et al.[14] and Najafi et al.[15] However, ARI scores of 2 and 3 were found mostly in the bis-acryl group which indicates that more adhesive was left on the provisional material than on the bracket. This demonstrates a stronger bond between the bis-acryl material and orthodontic adhesive resin which could possibly explain the high SBS in these materials. These findings are in agreement with the reporting of Graces et al.,[16] who found that bis-acryl material have high ARI scores compared to other provisional material. In this study, a magnification of 16x was used and results can vary with different magnification levels.[24] A low ARI score leaves less adhesive material on the crown promoting an easy removal from its surface. On the contrary, high ARI scores shows an opposite pattern where more residual adhesive is left on the crown surface. Thus, the removal of this adhesive becomes difficult and can also erode the surface of the crown material.[25]

While performing this study, standard guidelines and manufacturer's instructions were used for preparation of blocks, bonding of brackets and surface treatment. Further studies can be done with other class of material, different surface treatment methods, newer adhesive components or techniques to enhance the bond strength on provisional crown material.

CONCLUSION

In this study, the mean SBS was highest in the bis-acyl group and lowest in the auto-polymerizing PMMA group. No differences were found in the mean SBS values of auto-polymerizing PMMA, CAD/CAM PMMA and bis-acryl group. Sandblasting and application of CO_2 laser on the surface of CAD/CAM PMMA blocks lead to higher SBS than other methods. In the bis-acryl group, sandblasting the surface lead to higher SBS than other surface treatment methods.

Regarding the type of bond failure, most of the material presented with adhesive type failure with ARI scores of 0 and 1. In the bis-acryl group, debonding was more at the adhesive-bracket interface, indicating superior bond strength with the crown material.

CLINICAL SIGNIFICANCE

Bonding of orthodontic bracket to provisional crown is an important and indispensable step during the course of treatment. A provisional crown material combined with a better surface treatment method can enhance the bond strength of the bracket to the crown. This can improve the patient compliance and improve the standard of treatment.

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