ORIGINAL RESEARCH

Assessment of the Bond Strength of Orthodontic Bracket on Ceramic Crown Surface Using Three Various Bonding Agents: A Comparative Study

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Abstract

Aim: The current study's aim was to evaluate the orthodontic bracket's bond strength employing three different bonding agents on a ceramic crown surface.

Materials and methods: Tooth preparation on 60 permanent maxillary premolar teeth extracted for orthodontic purposes was carried out. Supragingival finishing margins were made for all samples, and ceramic (PFM) crowns were fabricated. Following crown cementation on the prepared samples, they were divided into three experimental groups randomly ($n = 20$) as follows: group I: Bracket bonding using Transbond XT bonding agent; group II: Bracket bonding using RelyX™ Unicem bonding agent; and group III: Bracket bonding using Assure Plus bonding agent. A universal testing machine was utilized to conduct the shear bond strength test. Using a stereomicroscope with a 10× magnification, adhesive remnant index scores were also used to assess the adhesive that was remaining on the surfaces. Data was recorded and statistically analyzed.

Results: The highest bond strength was found in RelyX™ Unicem bonding agent (19.38 ± 0.84) followed by Transbond XT bonding agent (17.12 ± 1.04) and Assure Plus bonding agent (16.14 ± 1.02). A highly significant difference was found between Transbond XT vs RelyX™ Unicem groups and RelyX™ Unicem vs Assure Plus groups. There was no significant difference found between Transbond XT and Assure Plus ($p > 0.001$). Adhesive Remnant Index scores showed that score 1 was higher [7 (35%)] in the Transbond XT bonding agent group. Score 1 was 8 (40%) and score 2 was 6 (30%) in RelyX™ Unicem bonding agent groups and in Assure Plus bonding agent group, score 2 was higher [9 (45%)].

Conclusion: In conclusion, RelyX™ Unicem exhibited superior bond strength with ceramic crowns when compared to Assure Plus and Transbond XT bonding agents.

Clinical significance: One of the most important steps in orthodontic therapy is bonding brackets to the teeth. A high enough and long-lasting bond between brackets and artificial surfaces is necessary for orthodontic treatment to be successful, as is the requirement for a bonding agent with the highest possible binding strength. The necessity for a more dependable process to glue the artificial crown surface has arisen due to the rise in adult patients seeking fixed orthodontic treatment.

Keywords: Adhesive remnant index, Bonding agents, Ceramic crown, Orthodontic brackets, Shear bond strength.

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Introduction

The global need for orthodontic treatment is rising since tooth alignment is a crucial factor in facial esthetics. The majority of adult patients have ceramic, amalgam, composite, gold, acrylic, or resin restorations, making glueing orthodontic brackets to dental restoration surfaces a typical requirement due to the rise in adult patients' demand for orthodontic treatment. Ceramic materials have been used much more frequently in dentistry restorations, including fixed crowns, in recent years.[1]

In orthodontics, the adhesive system used to attach brackets to ceramic or hard tissue surfaces must adhere to exact standards. The forces of orthodontic therapy and chewing motions in the warm, moist oral cavity must be withstood by the adhesive component. Moreover, neither the dental ceramic nor the hard tissue of the teeth should sustain any harm in the event of a planned bracket removal. According to studies, an adhesive force of 6–10 megapascals is needed to guarantee that the brackets adhere sufficiently for the collection and transmission of orthodontic pressures without running the risk of damaging the surface when removing the brackets.[2]

Common adhesive techniques cannot create an adhesive bind to brackets because ceramics is chemically inert and rarely

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reacts with potential reactants. To strengthen the adhesive bond between the ceramic and the bracket base, the ceramic surface must be pretreated chemically or mechanically. This pretreatment can be carried out chemically by etching with hydrofluoric acid or phosphoric acid, or mechanically using a bur, a laser, or sandblasting the surface.[3]

Transbond XT is one of the adhesives that is most frequently used in orthodontics. It is a hybrid resin made up of 82% 3µ silica particles and a 1:1 ratio of Bis-GMA and TEGDMA. Transbond XT exhibited acceptable shear bond strength (9–14 MPa), according to earlier research.[4] RelyX™ Unicem is a self-adhesive, dual-curing universal resin luting cement that can be used for indirect ceramic, composite, or metal restorations without the need for prior acid conditioning or bonding of the teeth serving as abutments. High dimensional stability and excellent adherence to the tooth structure are two of its key qualities.[5] In order to increase the stability of resin-dentin interfaces, Assure Plus bonding resin, which is recently available, is made up of BisGMA (10–30%) and ethanol (50–75%). This mixture encourages the infiltration of hydrophobic dimethacrylate resins into dentinal tubules and interfibrillar gaps.[6] There is very scarce data on the bond strengths of orthodontic brackets on ceramic crown surfaces. Therefore, utilizing three different bonding agents, the current investigation was carried out to evaluate the orthodontic bracket's bonding ability on a ceramic crown surface.

Materials and Methods

Samples Selection

The present *in vitro* study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Hazaribag College of Dental Sciences and Hospital, Jharkhand, India, during the years 2023–2024. And institutional approval was obtained. A total of 60 healthy permanent maxillary premolar teeth that were extracted for orthodontic purposes were used in the study. These teeth were free of cavities, fillings, hypoplasia, and other obvious defects. In order to stop bacterial development and dehydration, the teeth were kept in a 0.1% thymol solution. The teeth were first carefully cleansed for 10 seconds with fluoride-free pumice powder, then washed with water and dried with compressed air. The teeth were subsequently set into self-curing acrylic blocks so that the roots completely penetrated the acrylic, reaching the buccal surface of the crown and the cemento-enamel junction, which was perpendicular to the block's base.

Preparation of Crowns

The teeth were prepared by using a 330 bur to make depth cuts ranging from 1.5 to 2 mm. With a tapered diamond with a diameter of 0.7 mm, the axial walls were reduced. To attain a 1 mm chamfer margin for porcelain fused metal crowns, a minimum taper of 22–30 was required. After all completed margins were retained supragingival, imprints were taken and forwarded to a lab for crown preparation. Following the delivery of ceramic (PFM) crowns, luting glass ionomer cement (GIC) was used to cement the crowns to the prepared tooth surface.

Group Allocation

Following crown cementation, all samples were divided into three experimental groups (20 samples in each group) randomly, which were as follows:

Group I: Bracket Bonding Using Transbond XT Bonding Agent

The bonding surface of the crowns was coated with a small amount of Transbond™ XT light cure adhesive primer (3M, Unitek) and allowed to air dry. After lightly coating the bracket's base with Transbond™ XT adhesive resin (3M, Unitek), the bracket was placed onto the implanted crowns' bonding surface. A 300 gm force was applied to each crown to compress the bracket. An explorer was used to remove any excess resin, and a curing light (Ortholux LED, 3M Unitek) was used to light cure the resin for 40 seconds (20 seconds mesial and 20 seconds distal).

Group II: Bracket Bonding Using RelyX™ Unicem Bonding Agent

The premolar bracket base was coated with a modest amount of RelyX™ Unicem 2 Automix (3M, ESPE), and a similar bonding procedure was followed.

Group III: Bracket Bonding Using Assure Plus bonding Agent

The premolar bracket base was coated with Assure Plus bonding agent, and a similar bonding procedure was followed.

Debonding Procedure to Evaluate the Bond Strength

Prior to undergoing the shear bond strength test, each sample was bonded and then kept in distilled water for a whole day. Debonding forces were measured in Newtons using a universal testing machine (Instron, Canton, Mass.) operating at a crosshead speed of 1 mm/min. The machine was equipped with an adhesively bonded bracket and an embedded ceramic crown, with the bracket slot positioned horizontally. A shearing force was applied to the bracket–ceramic interface using a knife-edged shearing rod. The following formula was used to determine the shear bond strength (MPa).

Shear bond strength (MPa) = Shearing force (Newtons) / Bracket base surface area (mm^2).

Using a stereomicroscope with a 10× magnification, adhesive remnant index scores were also used to assess the adhesive that was remaining on the surfaces. Adhesive Remnant Index scores as follows:[7]

Score 0: The tooth has no adhesive remaining.

Score 1: Less than half of the adhesive is still on the tooth.

Score 2: The tooth still has more than half of the adhesive on it.

Score 3: The bracket mesh is clearly visible, and all adhesive is still present on the tooth.

Statistical Analysis

SPSS version 17 was used to analyze the data (SPSS Inc., IL, USA). The Shapiro–Wilk test indicated that the SBS data had a normal distribution. As a result, the ARI score was assessed using the Chi-square test, and the SBS data were evaluated using ANOVA. A *p*-value 0.05 was considered statistically significant.

Results

Table 1 shows the mean bond strength of three different bonding agents. The maximum shear bond strength was found in RelyX™ Unicem bonding agent (19.38 ± 0.84) followed by Transbond XT bonding agent (17.12 ± 1.04) and Assure Plus bonding agent

Table 1: Evaluation of the mean shear bond strength of three various bonding agents

Groups	*Mean ± SD*	*F Value*	*p-value*
Group I: Transbond XT bonding agent	17.12 ± 1.04	29.043	0.0001***
Group II: RelyX™ Unicem bonding agent	19.38 ± 0.84		
Group III: Assure Plus bonding agent	16.14 ± 1.02		

$p < 0.05$, ***Highly significant

Table 2: Evaluation of multiple comparisons of various bonding agents using Tukey's *post hoc* test

Experimental groups	*Comparison with*	*Mean differences*	*Significance*
Transbond XT	RelyX™ Unicem	–2.26	0.001
	Assure plus	0.98	0.07
RelyX™ Unicem	Transbond XT	2.26	0.001
	Assure Plus	3.24	0.001
Assure Plus	Transbond XT	–0.98	0.07
	RelyX™ Unicem	–3.24	0.001

Table 3: Adhesive remnant index scores of various bonding agents

Groups	*N*	*Score 0*	*Score 1*	*Score 2*	*Score 3*
Group I: Transbond XT bonding agent	20	4 (20%)	7 (35%)	6 (30%)	3 (15%)
Group II: RelyX™ Unicem bonding agent	20	5 (25%)	8 (40%)	6 (30%)	1 (5%)
Group III: Assure Plus bonding agent	20	3 (15%)	5 (25%)	9 (45%)	3 (15%)

Chi-square (χ^2) = 18.02; $p = 0.718$

(16.14 ± 1.02). A significant difference was found between the three bonding agent groups.

Table 2 depicted the multiple comparisons of various bonding agents using Tukey's *post hoc* test. A significant difference was found between Transbond XT vs RelyX™ Unicem groups and RelyX™ Unicem vs Assure Plus groups ($p < 0.001$) and there was no significant difference found between Transbond XT and Assure Plus groups ($p > 0.001$).

Table 3 shows the Adhesive Remnant Index scores of three different groups. Score 1 was higher [7 (35%)] in the Transbond XT bonding agent group. Score 1 was 8 (40%) and score 2 was 6 (30%) in RelyX™ Unicem bonding agent groups, and in Assure Plus bonding agent group, score 2 was higher [9 (45%)]. The Chi-square test showed there was no significant difference between the groups. The mode of failure was mixed in all three groups.

The inference of the study indicates that RelyX™ Unicem showed better bond strength with ceramic crown compared to Transbond XT and Assure Plus bonding agents.

Discussion

The success of orthodontic therapy is largely dependent on the orthodontic fixed appliances being retained adequately during the whole course of treatment, as opposed to a course of treatment that entails several instances of bracket debonding.[8] For the purpose of bonding orthodontic brackets together, several adhesive agents have been created. The groundbreaking work played a key role in creating the methods and supplies that eventually led to the standards for orthodontic adhesives that exist today. These early attempts led to the development of acid etching, GICs, self-curing composite resins, and visible light-curing adhesives. In order to enhance the quality of the bindings between brackets and teeth or artificial surfaces, technologies utilizing novel materials are continuously developing.[9]

Research on the shear, tensile, and torsion strengths obtained from *in vitro* orthodontic bond strength testing, as well as the clinical methods, material types, and appliance designs, have been published in the literature. For this, universal testing apparatuses like Instron have been employed. In the current investigation, a universal testing apparatus running at a crosshead speed of 1 mm/min was used to measure debonding forces in Newtons. Orthodontic bond strength tests were not significantly affected by crosshead speeds ranging from 0.1 to 5 mm/min, as demonstrated by Klocke and Kahl-Nieke.[10]

One of the adhesives that are most commonly used in orthodontics is Transbond XT. It is a hybrid resin consisting of a 1:1 ratio of Bis-GMA and TEGDMA with 82% 3μ silica particles. Previous studies found that Transbond XT has an adequate bond strength of 9–14 MPa. For indirect ceramic, composite, or metal restorations, RelyX™ Unicem is a self-adhesive, dual-curing universal resin luting cement that can be employed without the requirement for earlier acid conditioning or bonding of the teeth acting as abutments. Two of its most important characteristics are high dimensional stability and great adhesion to the tooth structure. Assure Plus bonding resin, recently available, is composed of 50–75% ethanol and 10–30% BisGMA to improve the integrity of resin-dentin surfaces. The penetration of hydrophobic dimethacrylate resins into dentinal tubules and interfibrillar gaps is promoted by this mixture.[5,6] Hence these three different bonding agents used in the present study.

According to the current investigation, RelyX™ Unicem bonding agent had the strongest bond, followed by Transbond XT and Assure Plus bonding agents. Due to its one-step adhesion process, long-term stability, minimal expansion, and sufficient tensile strength—all of which are especially important when cementing orthodontic brackets—RelyX Unicem is a dual-cured universal adhesive cement that have shown to be appropriate for effective orthodontic bonding. Jivanescu and Bratu[5] evaluated the RelyX™ Unicem self-adhesive resin against a light-cured bonding method on porcelain-fused to metal crowns that were conditioned with 10% HFA, a primer, and an adhesive. Between the light cured bonding system and the RelyX™ Unicem resin (SBS-5.18 MPa), no statistically significant difference was seen. They came to the conclusion that it might be advisable to use both materials for adhering orthodontic brackets to ceramic surfaces. A study conducted by Liu et al.[11] investigated and confirmed that RelyX Unicem's bond strength was much higher than that of other resin cements that showed a high percentage of cohesive failures.

In the current investigation, the bonding agent Assure Plus had the lowest SBS. It is similar to the research done by Littlewood et al.,[12] which found that even with the use of hydrophilic primers, Assure Plus's bond strength was lower than that of the traditional primer Transbond XT because all of the tests were carried out in dry environments. In contrast to the current investigation, where 9.6% H.F. was used to etch the ceramic surface prior to the application of a silane coupling agent, Toodehzaeim et al.[13] indicated significantly reduced bond strengths of 8.85 MPa since the surface was just sandblasted and not etched.

Ideally, the time-saving purpose not only applies for bonding purposes but also interests the debonding and removal of the residual resin from the tooth surface, which are crucial for an efficient and ideal workflow. Less time will be needed, more adhesive material will be bonded to the bracket base, and the process will be simple and safe. ARI, a three-scaled quantification scoring system for leftover adhesive proposed by Artun and Bergland,[7] is one of the often used indices to test adhesive material in orthodontics.

The present study showed that there were more bond failures at the adhesive-crown interface in the tested samples, which is in accordance with the results of the Fleischmann LA et al.[14] study. According to the findings of the studies by Chang WG et al.[15] and Bishara SE et al.,[16] the low ARI scores of 0 and 1 are favorable because they indicate less iatrogenic damage during surface polishing and less adhesive residual on the enamel surface.

For clinical situations, the utilization of RelyX™ Unicem bonding agent may result in a lower debonding rate and also reduce damage to the crown. This study had limitations that should be considered when interpreting the results. The failure mode may have been impacted by the study circumstances, namely the SBS test, which did not replicate the clinical orthodontic bracket removal environment. Furthermore, the mouth cavity offers a unique testing environment in terms of salivary flow, pH levels, and temperature fluctuations, all of which may have impacted the results. Future studies are required to evaluate the efficacy of different types of bonding agents with different surface treatments.

Conclusion

Within the limitation, the current investigation concluded that RelyX™ Unicem exhibited superior bond strength with ceramic crown in comparison to Transbond XT and Assure Plus bonding agents. Bond failure at the bracket and crown interface may have been caused by the adhesive nature of the bond. This type of failure can be favorable for orthodontics as it minimizes the damage to the bonded surfaces. Although this study produced optimistic findings, more *in vivo* testing is required to ascertain the actual therapeutic efficacy of direct bonding to artificial crowns.

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