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EVALUATION OF SHEAR BOND STRENGTH OF BAND CEMENTATION WITH DIFFERENT CEMENTATION MATERIALS

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ABSTRACT

Introduction: Band retention mainly depends on how bands are positioned on the teeth and the properties of the cement used, whether chemically or light-cured. The strength of the bond between the band, cement, and enamel is essential for effectively transferring forces to the teeth. Dynamic intraoral stresses from mastication and occlusion can influence the bonding strength of bands.

Aim of the study: Assessing the shear bond strength of light-cured, dual-cured, and chemically-cured cements in band cementation.

Materials and methods: The teeth were randomly divided into three groups, each with 12 teeth, based on the tested materials: group (A)→BracePaste®, group (B) Breeze™ Resin Cement, and group (C) Fusion Self Lute. Bonding of the brackets in each group was performed according to the manufacturer's guidelines. Shear bond strength (SBS) was measured using a universal test machine.

Results: No significant difference in the SBS was found between Breeze dual-cure resin cement and Bracepaste light-cure resin cement. Statistically significant differences in the SBS were present between Breeze dual-cure resin cement and Fusion self-cure resin cement. Finally, a significant difference in the SBS was reported between Bracepaste light-cure resin cement and Fusion self-cure resin cement.

Conclusion: It was concluded that Breeze dual-cured resin cement demonstrated the highest SBS when compared to BracePaste light-cured resin cement and Fusion chemical-cured resin cement.

KEYWORDS: Shear bond strength, bands, luting cements.

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INTRODUCTION

A contributor to the success of the orthodontic fixed appliance therapy, as well as space maintainers in pediatric dentistry, is the reliable attachment of the bonded or banded components to the teeth. Therefore, the appliances must withstand chewing forces throughout the treatment period[1].

Bonded attachments are commonly utilized in fixed appliance therapy; however, bands are still favored over bonded tubes for molars and premolars[2]. Orthodontic bands are pre-shaped metal bands that fit around the teeth and are secured in place with cement. These bands are used to attach brackets and appliances securely to the teeth[3].

Orthodontic bands must meet several requirements, including adequate adhesive strength, smooth placement, protection against dental caries, and affordability. While the bands are exposed to chewing forces that create shearing stress at the bonding interface, they must also effectively transfer these forces to the teeth[4]. Orthodontic bands are regarded as a key method for correcting severe crowding or spacing in orthodontic treatment[5]. Most importantly, orthodontic bands are used when applying space maintainers, such as the Nance palatal and lingual arch[6]. One issue encountered during band cementation is the dissolution of the cement, which can lead to microleakage. This allows food to accumulate beneath the band, making it difficult for the patient to brush and floss properly. Over time, this can result in the development of caries around the band and, eventually, periodontal disease[7]. It is essential to consider the properties and characteristics of the dental materials involved and select the appropriate product for optimal performance. The ideal cement should offer sufficient retentive forces to withstand normal masticatory pressures [8]. A broad scope of resin luting cements is used in band cementation, including light-cure, fluoride-releasing, dual-cure, and self-cure luting composites [9, 10]. Composite resins, introduced by Buonocore[11], are commonly utilized for bracket bonding due to their bond strength, which increases and doubles within 24 hours[12]. The resin composite requires acid etching of the tooth enamel to create micro-mechanical retention, followed by applying the primer to facilitate bonding [13]. Photo-polymerized cements cure in about 30 seconds when exposed to a light with the correct wavelength [14]. The acid-base reaction continues even after the photo-polymerization process is complete, further enhancing the material's mechanical properties. The challenges of hand-mixing powder and liquid were addressed through the use of encapsulated paste with fixed proportions, as per the manufacturer's instructions, and mechanical mixing. The ongoing challenge to enhance the structure and mechanical qualities of the cements remains of great interest. The refinement of filler particles and their integration into the resin matrix are continuously improved to develop new products for dental needs. Examples of dental cements with newly improved formulations include: resin cement (e.g., Transbond), resin-modified glass ionomer RMGIC (e.g., Fuji Ortho), and resin composites (e.g., BracePaste). An essential demand of dental materials is their ability to withstand masticatory forces, as the bonding film between the metal brackets and enamel is influenced in a complex way by factors such as flexing, peel, compression, and shear.

Aggarwal M et al. 2000 evaluated five cements and concluded that RMGIC and polyacid-modified composite resin cement (PMCR) require higher forces to debond compared to zinc phosphate cement [15]. Farret MM et al. 2012 assessed two types of glass ionomers and RMGI, concluding that RMGI exhibited superior mechanical properties compared to conventional glass ionomer(16). Maranhao KM et al. 2018 reported that there was no significant difference in shear bond strength (SBS) of bands cemented with a new composite adhesive system[17]. Omidkhoda M et al. 2023 found that the self-cure adhesive exhibited higher shear bond strength than the light-cure adhesive [18].

AIM OF THE STUDY

Evaluation of the shear bond strength of light-cured, dual-cured, and chemically-cured cements when used for band cementation.

MATERIALS AND METHODS

It is a laboratory in vitro study. Ethical approval was obtained from the Unit of Research Ethics Approval Committee (UREAC), Pharos University in Alexandria (approval No. 172/27-1-2024).

Sample size estimation

Sample size was calculated using power analysis and sample size software (PASS 2020), "NCSS, LLC, Kaysville, Utah, USA, ness.com/software/pass". The minimal total hypothesized sample size of 36 sampling units (12 per group) is needed to compare three different cement materials and to know which one has more bond strength than the other using metallic bands and extracted teeth (premolars) using the universal testing machine in Alexandria university; taking into consideration an effect size of 30%, significant level of 5% and power of 80% using chi-square test[19, 20].

Assessment of SBS

Twelve premolars were randomly allocated to one of the groups using a computer-generated random number program. Premolars were examined using a stereomicroscope (Kruss, Hamburg, Germany) with 20× magnification. Premolars collected for periodontal or orthodontic purposes were acquired from the Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Pharos University in Alexandria. The premolars were free of surface cracks, restorations, cavities, white spot lesions, and prior chemical treatments. After being thoroughly cleaned of blood and debris by a rubber cup, the teeth were polished using fluoride-free pumice paste. Extracted teeth were kept in a solution of deionized water saturated with 1% thymol, which was changed daily, until they were used[21]. The study used pre-formed, unwelded stainless steel premolar bands from Dentaurum in Ispringen, Germany. The procedure began by embedding the teeth in a wax mold, with each tooth oriented so that its occlusal surface was parallel to the floor. Cold-curing, fast-setting acrylic resin was poured, and after polymerization, the samples were ready for the cementation procedure[22]. Stainless steel bands were selected by measuring the bucco-lingual and mesio-distal widths of the tooth using a digital caliper (Mitutoyo Corp, Tokyo, Japan). The appropriate size of the stainless-steel maxillary premolar bands was selected and adapted to the crown of each tooth. The same operator selected and placed the bands to eliminate any potential operator bias in positioning and fitting. The teeth were randomly allocated to three groups, each containing 12 teeth, based on the tested materials:

Group (A)→BracePaste® Band and Build LC Band Cement (light cure) American

Orthodontics, Sheboygan, WI, USA.

Group (B)→Breeze™ Resin Cement, Pentron Clinical Technologies, LLC, 68 North Plains Industrial Road, Wallingford, CT, USA 06492 (dual cure).

Group (C)→Fusion Self Lute® Self-curing polymer Resin luting Cement (base and catalyst) (chemical cure)

The bands were sectioned from the mesial and distal sides to be placed on the buccal and palatal tooth surfaces. The premolar bracket was welded onto a band segment using a welding machine. Finally, the bands were cemented following the manufacturer's instructions for each type of cement. As the first step, each tooth was etched via 37% phosphoric acid (Total Etch, Ivoclar Vivadent, Schaan, Liechtenstein) for 30 seconds. Then, rinsing the teeth with a water spray for 30 seconds and air-dry for 20 seconds[23].

Bonding procedure[23]:

Group (A): After etching, each tooth in Group (A) was cemented with BracePaste light-cure resin cement. Following the manufacturer's instructions, an adequate amount of BracePaste cement was placed on the band. The band segments were then positioned on the buccal and palatal surfaces of the tooth. Excess cement around the band was gently removed using an explorer, and the bands were light-cured for 20 seconds each.

Group (B): Self-adhesive resin cement was used as stated in the manufacturer's instructions. A sufficient amount of Breeze resin cement was applied to the band, and the band segments were adapted to the tooth. Excess cement around the band was gently removed with an explorer. The bands were then light-cured using an Ortholux LED light (3M Unitek Orthodontic Products, Ontario, Canada) for 20 seconds. The final set occurred after 3-4 minutes via chemical curing.

Group (C): After etching, each tooth in Group (C) was cemented with Fusion self-cure resin cement.

As reported by the manufacturer's instructions, a sufficient amount of Fusion cement was applied to the band. The band segments were then placed on the tooth, and excess cement around the band was gently removed with an explorer. The initial cement setting occurred within 2-2.5 minutes, while the final setting took place after 3-4 minutes. After the final setting, all samples were transferred to three plastic containers and immersed in distilled water at 37°C for 24 hours[24].

For the shear bond strength (SBS) test, a universal testing machine (Instron, USA) was used. The maximum strength at the time of rupture was documented in newtons (N) and then transformed into megapascals (MPa), Fig. 1, showing a mounted sample on the universal testing machine.

Statistical analysis

Data was fed to the computer and analyzed using R programming version 4.3.3. Quantitative data were described using mean, standard deviation, range (minimum and maximum), or median and interquartile range (IQR). Significance of the obtained results was judged at the 5% level, and the confidence interval was at 95%. Kruskal-Wallis's and Mann-Whitney U statistical tests were used for non-parametric distributed quantitative variables to compare two categorical groups.

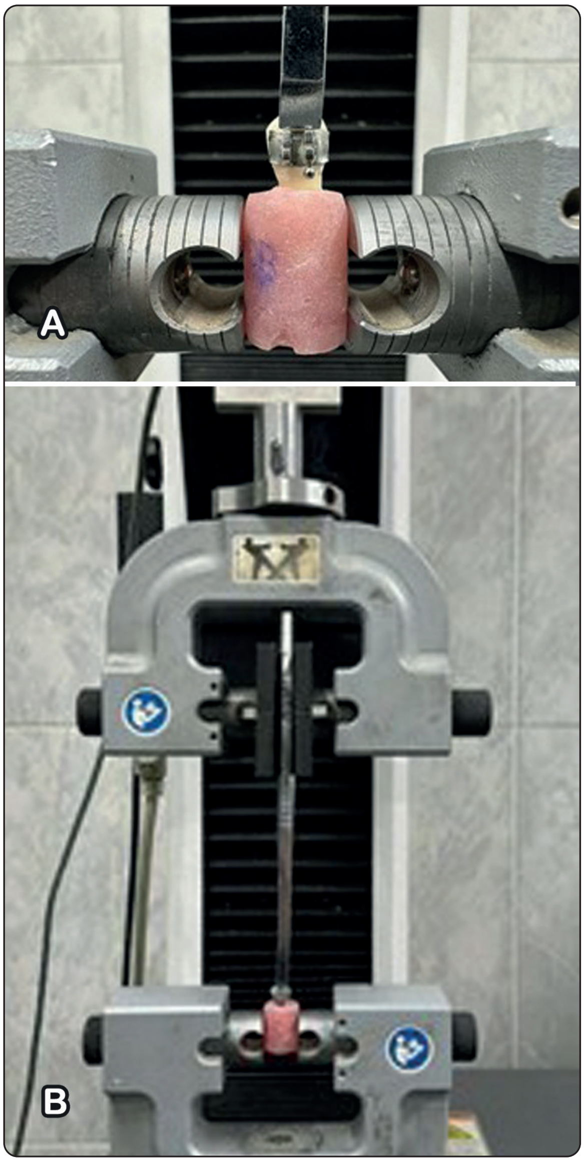

Fig. (1) Showing a mounted sample on the universal testing machine

TABLE (1) Pairwise Comparison between the groups A, B, C according to SBS.

Characteristic	Group (A)	Group (B)	Statistical test value	p-value
Variable	Gp (a)	Gp (b)		
Median (IQR)	31 (13)	86 (75)	38	0.052[a]
Range	(23.52 4.81)	(25.69 -136.16)		
Variable	Gp (a)	Gp (c)		
Median (IQR)	31 (13)	12 (24)	115	<0.05 (0.014)[a]
Range	(23.52 4.81)	(2.58 -51.35)		
Variable	Gp (b)	Gp (c)		
Median (IQR)	86 (75)	12 (24)	128	<0.05 (0.001)[a]
Range	(25.69 -136.16)	(2.58 -51.35)		

p value (<0.05) was considered significant using When you can apply the Mann-Whitney U test (a)

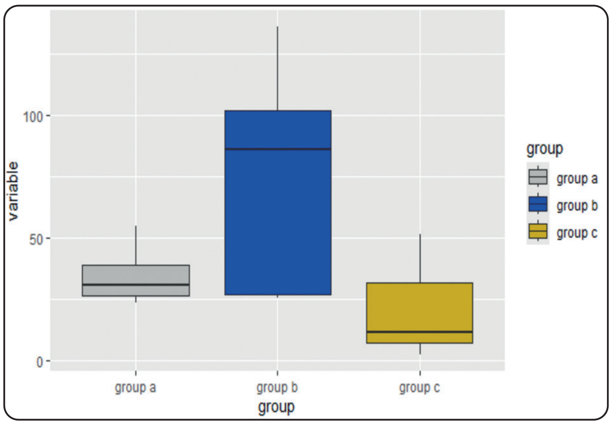

Fig. (2) A box plot illustrating the significant difference between the 3 groups (A) bracepaste light cure resin, (B) breeze dual cure and (C)Fusion self-cure resin cements.

RESULTS

According to the results, there was no significant difference in the SBS between Bracepaste light-cure resin cement and Breeze dual-cure resin cement, with p p-value of 0.052. On the other hand, there was a significant difference in the SBS between the breeze dual-cure resin cement and the Fusion self-cure resin cement, p value=0.001. Added to that, there was a significant difference in the SBS between Bracepaste light-cure resin cement and Fusion self-cure resin cement, p value=0.014. Breeze dual-cured resin cement exhibited the highest SBS with median (IQR)=86(75), Tabel 1. .

DISCUSSION

Although the stresses at the band-tooth interface are complex, they can primarily be classified as shear or tensile stresses. Bands are more likely to loosen and fail due to the tensile and shear forces applied during mastication[22]. Furthermore, it has been shown that the forces applied to bands during mastication are primarily shear. As a result, this method may effectively simulate the clinical setting [25]. Shear bond strength is evaluated for its repeatability and its ability to combine shear and peel forces[26]. Bond strength should be high enough to prevent appliance failure during treatment, yet low enough to allow debonding without damaging the enamel[27]. Comparing this study with previous research was challenging due to the use of different cements. This study aimed to compare the most commonly used orthodontic resin luting cements with different curing techniques, focusing on improved handling characteristics and bond strength. In this study, all the luting cements released fluoride.

In the present study, the application of the luting cements was directly to the enamel surfaces without any restorative materials, allowing for the assessment of shear bond strength to the tooth structure without interference from restorative materials. For this reason, sound teeth were selected.

The results of the current study align with those of Zaidan S.M. and Rafeeq R.A. (2022)[28], where the mean SBS of TOTALCEM (self-adhesive resin cement/dual cure) was significantly higher than that of both Transbond Plus Light Cure Band Adhesive (compomer) and RelyX Luting Resin Modified Glass Ionomer. Moreover, the results matched the study by Sabatini et al.[29], which found no significant difference between RelyX Luting 2 and Transbond Plus Light Cure band adhesive. This agrees with the reports of Millet et al.[30], Agrawal et al.[15], and Caglaroglu et al.[31].

The results of the involved study showed that Breeze dual-cured resin cement exhibited the highest SBS. This significant retention may be attributed to its dual retention mechanism, which bonds to etched surfaces. Clinicians may also benefit from its favorable working time, simple manipulation, auto-mixing capability, fluoride release, and elimination of the priming procedure. Additionally, micromechanical retention between the metallic band and the enamel hydroxyapatite contributes to the bond strength[32].

This contrasts with the results of Iosif C et al.(4), who reported that BracePaste provided the best configuration for strong adhesion between the enamel interface and brackets. Additionally, Premnath K et al. 2023, found a high, though non-significant, SBS value for Fusion Self Lute, which contains silane nano-ceramic filler particles. The differences in the results of the present study may be attributed to variations in methodologies compared to those used in other studies[33].

CONCLUSION

It was concluded that Breeze dual-cured resin cement demonstrated the highest SBS when compared to BracePaste light-cured resin cement and Fusion chemical-cured resin cement. However, given the limitations of in vitro studies, long-term clinical studies are needed to compare the bond strength of different luting materials. Since bands are clinically used for a long period of time, it would be beneficial to evaluate the cement retentive properties past the 24 hours. A second limitation of the current study was that the band cementation was done on a dry surface, which is difficult to achieve clinically in children, especially in the lower arch dentition. Thus, investigating the effect of moisture on the mechanical properties of the cements would produce valuable clinical insights. Furthermore, assessing SBS under clinical conditions is essential due to the many factors associated with the oral environment. Increasing the sample size would also enhance the effectiveness of the study. Thermal aging, using a thermocycling procedure, should be employed to more accurately mimic oral conditions. In conclusion, further in vivo studies are recommended to evaluate the physical properties of Breeze dual-cure resin cement under clinical conditions.

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