THE EFFECT OF BEVEL ON FRACTURE RESISTANCE OF GIC RESTORATIONS IN PRIMARY MOLARS: AN *IN VITRO* STUDY

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Introduction: Glass ionomer cements (GICs) are commonly used for restorations in primary molars due to their adhesive, hydrophilic, and bioactive properties. However, their low mechanical resistance may limit their use in proximal cavities. Recent advancements in GICs, such as the high viscosity GIC EQUIA Forte®, have improved their mechanical properties. The effect of a Cavo superficial bevel on the mechanical strength of GIC restorations has been previously studied.

Objectives: To investigate the effect of a Cavo superficial bevel on fracture resistance and the type of fracture (adhesive, cohesive, or catastrophic) in EQUIA Forte® GIC restorations in primary molars.

Methods: A total of 66 standardized proximal cavities were created on 51 temporary molars. The cavities were randomly divided into two groups: group I without a Cavo superficial bevel (n=33) and group II with a 45° Cavo superficial bevel (n=33). The cavities were restored with EQUIA Forte®. The samples were subjected to thermocycling and artificial aging, then, an axial speed loading of 1 mm/min was applied until fracture. Fracture toughness was recorded, and the type of fracture was observed under an optical microscope. A Mann-Whitney U test was used to compare the average fracture resistance between the groups. All tests were two-tailed and the level of significance was set at 5%.

Results: The average fracture resistance for group I was (237.57 ± 139.97 N) and for group II was (294.89 ± 171.07 N). There was no statistically significant difference in fracture resistance between the two groups ($p>0.05$). Mixed fractures were observed in all samples, with adhesive fractures only present in group I and cohesive fractures only present in group II.

Conclusions: The Cavo superficial bevel does not significantly affect the fracture resistance of GIC restorations in primary molars. However, the bevel design may prevent adhesive and catastrophic fractures.

Keywords: Bevel, GIC, Class II, Primary molars, Restoration, Type of fracture

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Conflicts of interest:
The authors declare no conflicts of interest.

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RÔLE DU BISEAU DANS LA RÉSISTANCE À LA FRACTURE DES RESTAURATIONS AUX CIMENTS VERRES-IONOMÈRES DES MOLAIRES TEMPORAIRES: ÉTUDE IN VITRO

Introduction: Les ciments verres-Ionomères (CVI) sont couramment utilisés pour les restaurations des molaires temporaires grâce à leurs propriétés adhésives, hydrophiles et bioactives. Cependant, leur faible résistance mécanique limite leur utilisation dans les cavités proximales. Avec les récents progrès de cette classe de matériaux, un CVI à haute viscosité a été introduit : EQUIA Forte®, visant à améliorer leurs propriétés mécaniques. Le rôle du biseau Cavo-superficiel sur la résistance mécanique des restaurations au CVI a déjà été étudié.

Objectifs: Tester le rôle du biseau dans l'amélioration de la résistance à la fracture et d'étudier la nature du trait de fracture adhésif, cohésif, ou catastrophique des restaurations aux CVI EQUIA Forte® des molaires temporaires.

Méthodes: Au total, 66 cavités proximales standardisées ont été réalisées sur 51 molaires temporaires. Ces cavités ont été divisées aléatoirement en deux groupes : groupe I sans biseau Cavo-superficiel (n=33) et groupe II avec biseau Cavo-superficiel de 45° (n=33). Les cavités ont été restaurées par EQUIA Forte®. Les échantillons ont été soumis à un thermocyclage et à un vieillissement artificiel, puis une vitesse axiale de chargement de 1 mm/min a été appliquée jusqu'à la fracture. La résistance à la fracture a été enregistrée et le type de fracture a été observé au microscope optique. Le test de Mann-Whitney U a été utilisé pour comparer la résistance moyenne à la fracture entre les groupes. Tous les tests étaient bilatéraux et le niveau de signification a été fixé à 5 %.

Résultats: La résistance moyenne à la fracture pour le groupe I était de (237,57 ± 139,97 N) et pour le groupe II était de (294,89 ± 171,07 N). Il n'y avait pas de différence statistiquement significative en termes de résistance à la fracture entre les deux groupes ($p > 0,05$). Cependant, des fractures mixtes ont été observées dans tous les échantillons, les fractures adhésives étant uniquement présentes dans le groupe I et les fractures cohésives présentes uniquement dans le groupe II.

Conclusions: Le biseau Cavo-superficiel n'influence pas de manière significative la résistance à la fracture des restaurations CVI des molaires temporaires. Cependant, il s'est avéré que la conception du biseau empêche les fractures adhésives et catastrophiques d'avoir lieu.

Mots clés: Biseau, CVI, Classe II, Molaires Temporaires, Restauration, Type de fracture

Introduction

Dental caries is a common problem in children, particularly affecting primary molars due to their weak mineralized enamel structure, thin dentin layer, and large pulp chamber. For over fifty years, composite restorations have been used to treat cavities. However, composite often undergoes considerable shrinkage after polymerization, resulting in a leaky margin that allow bacterial penetration and secondary caries. In order to overcome the drawbacks associated with composite, dentists have turned to alternative materials. Nowadays, GICs are proving to be the products of choice for the restorations of primary molars. Nevertheless, the fracture of the GICs proximal restorations remains a primary cause for restoration replacement [1-3].

Class II restorations in primary molars have a lower success rate compared to class I restorations due to factors such as bacterial microleakage, poor sealing, lack of adhesion and fractures. Recent studies have investigated the effect of the geometric shape of bevel on the control of microleakage, adhesion, and fracture resistance in class II cavities. In addition, numerous studies have demonstrated that GIC-EQUIA Forte® is the ideal product of choice in pediatric dentistry, given the significant improvement in microleakage, and fracture toughness compared to other products [4-6].

This study aims to investigate the effect of a Cavo superficial bevel on fracture resistance and the type of fracture in EQUIA Forte® GIC restorations in primary molars.

Materials and Methods

Methods

Sample selection

The Ethics committee (Tfemd/2022/35) granted approval for this study, which was conducted at the Laboratory of Biomaterials, St Joseph University in Beirut, Lebanon. To determine the sample size, a power analysis for an independent Student's t test was conducted using G*Power software 3.1.9.7 for Windows (Heinrich Heine, Universitat Düsseldorf, Düsseldorf, Germany). A power of 0.8, an alpha level of 0.05, and a large effect size of 0.8 were considered. The minimum required sample size was determined to be 52 in total, with 26 samples allocated to each group. The fifty-one temporary molars selected for this study had been extracted for reasons unrelated to the study. Molars with previous restorations, fractures, or any other defects that could potentially impact the results were excluded from the study. To ensure optimal preservation, the teeth were stored in distilled water for no longer than three months. Subsequently, the molars were randomly divided into two groups (I and II), with 33 cavities present in each group. Group I consisted of Class II cavities without a bevel, serving as the control group, while Group II consisted of Class II cavities with a bevel.

Specimens preparation

A single operator performed the specimen preparation. The teeth were placed in acrylic resin molds to replicate the oral environment. A pear-shaped diamond bur (830-008 Medium NTI FG; Head length 2,5 mm; Germany) specifically designed for pedodontics was utilized under continuous irrigation to prepare the cavities. The size of the cavities was standardized by outlining them with an indelible pencil. The depth of the cavities was 2 mm from the pulp wall to the cervical wall, 4 mm from the occlusal to the gingival surface, 3 mm from the vestibular-palatal/lingual of the cervical wall, 2.5 mm from the vestibular-palatal/lingual of the proximal occlusal surface, 1.5 mm at the isthmus, and 2 mm at the dovetail. In group II, a 45° Cavo-superficial bevel of 1 mm extent was created using a tapered diamond bur (845-012 Coarse NTI FG; Head length 3.5 mm; Diamond Flat End Taper; Germany). To standardize the beveled angle to the required value, a specially designed metallic device angled at 45° was used for continuous measurement. EQUIA Forte® Fil (Equia FF; Equia Forte Fil, GC Dental Products Corp, Tokyo, Japan) was used to fill the cavities following the manufacturer's instructions. The resulting restorations were sculpted with precision to match the natural anatomy of primary molars.

Assessment of fracture resistance

The specimens were artificially aged by undergoing 1000 thermocycles between 5°C and 55°C before being tested for fracture resistance. The fracture resistance of the specimens was tested using a universal testing machine (YLE GmbH - YL-01 series, Testing Software Manual, Gujarat, Germany) operated by a laboratory technician specialized in using the machine. A 4.5 mm diameter conical steel cylinder was applied perpendicularly to the occlusal plane and directed towards the long axis of the tooth until the restoration fractured, at a speed of 1 mm/min. The force applied, through the use of a universal testing machine, was 10 kN (kilonewton) until the restoration reached its fracture point. At the moment of fracture, the machine recorded the force and displayed it in newton (N) on the panel. The type of fracture was then observed under an optical microscope (Zeiss Extaro 300, Oberkochen, Germany) at a magnification of x25.

During the experiment, some specimens developed abrupt cracks, possibly due to inadequate positioning in the universal testing machine. As a result, these specimens were excluded from further analysis, leading to a decrease in the initial sample size from 33 cavities per group to 28 cavities per group.

Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, NY,

USA). Descriptive statistics of the quantitative variables were summarized and presented as medians (Q1 – Q3), means ± standard deviations, and minimum and maximum values. The normal distribution of the quantitative outcome variable was assessed using the Kolmogorov-Smirnov test. As the outcome variable of fracture resistance did not follow a normal distribution, the non-parametric Mann-Whitney U test was used to compare the fracture resistance between groups. All tests were two-tailed and the level of significance was set at 5%.

Results

Descriptive statistics of the fracture force and comparison between groups are shown in Table 1. A graphical representation of the results is displayed in Figure 1. Although group II showed a higher fracture resistance mean (294.89 ± 171.07 N) than group I (237.57 ± 139.97 N), the difference was not statistically significant according to the Mann-Whitney U test (p-value = 0.193).

Each group displayed distinct fracture patterns. In the unbeveled group, adhesive fractures were predominantly observed (Figure 2a), indicating the detachment of restorations. Fractures along the tooth enamel edges of the cavity were also observed (Figure 2b). Additionally, catastrophic fractures, representing severe longitudinal vertical fractures, were noted in this group (Figure 3).

In the beveled group, a combination of both adhesive and cohesive fracture types was observed (Figure 4). However, fractures of the GIC-EQUIA Forte® material were only observed at a distance from the bevel.

Table 1. Comparison of the fracture resistance (N) between groups

	N	Minimum	Maximum	Mean	SD	Q1	Median	Q3	*p*-value
Group I	28	57	598	237.57	139.96	126.5	238.0	333.25	0.193
Group II	28	90	792	294.89	171.07	160.75	260.0	364.0	

Group I: Unbeveled; Group II: Beveled; SD = standard deviation; Q1 = first quartile; Q3 = third quartile.

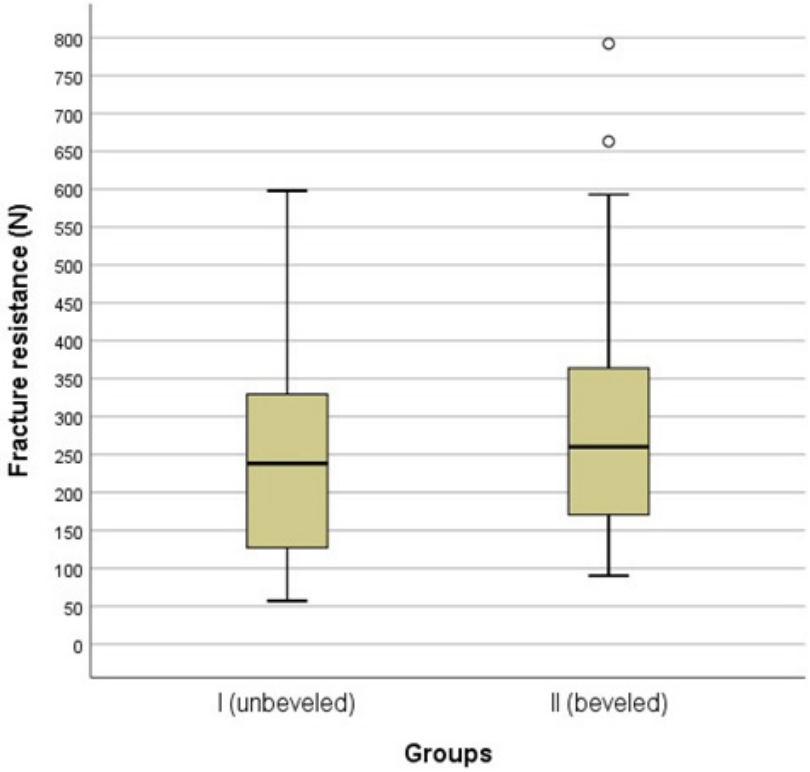

Figure 1. Box-plots of the fracture resistance among the groups.

Figure 2a. Microscopic examination of adhesive fracture.

Figure 2.b. Microscopic examination of coronary enamel fractures in unbeveled samples using the Zeiss Extaro 300 Microscope (Magnification: x25)

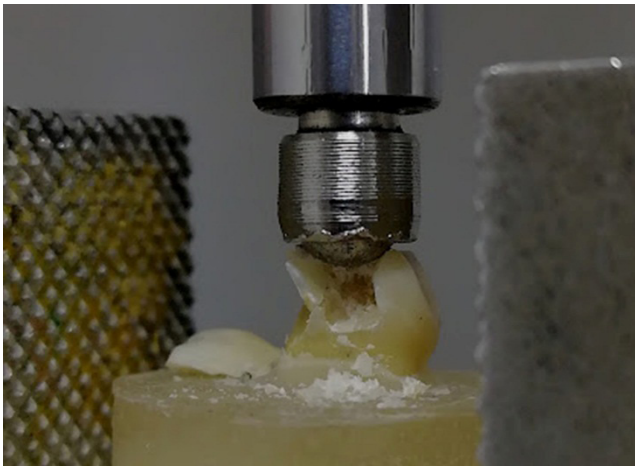

Figure 3. Catastrophic severe longitudinal vertical fractures observed in unbeveled samples.

Figure 4. Microscopic examination of cohesive fractures in marginal areas in beveled samples using the Zeiss Extaro 300 Microscope (Magnification: x25)

Discussion

This experimental study was conducted to evaluate the fracture resistance of GIC-EQUIA Forte® restorations in conventional class II cavities and modified by the addition of a bevel. The teeth selected for this study were subjected to identical conditions. with a single practitioner performing all cavities, restorations, and machine manipulation in the laboratory to eliminate sample handling bias. The overall result of this study showed that modifying the Cavo superficial angle by adding a bevel did not have any impact on the fracture resistance of the GIC-EQUIA Forte® restorations. Thus, the null hypothesis was validated.

In the literature, the information given on the design of the bevel is still under discussion. Some researchers and clinicians believe that the Cavo superficial bevel is a less conservative approach as it removes healthy tooth structure. In a clinical study, Coelho-De-Souza et al. (2012) demonstrated that the beveled architecture did not affect the mechanical performance of posterior composite restorations after 1 year [7]. Similarly, a recent in vitro study, Soliman et al. (2016) showed that the bevel did not to improve the qualities of a large proximal box composite restorations. Consequently, the use of a bevel is not recommended in large Class II box cavities where the residual enamel is already weak [8]. Carvalho et al. (2000) found that beveling further expose the surface of the composite restoration to masticatory forces and wear, resulting in a thinner thickness at the beveled zone that is more susceptible to fracture [9]. These findings were consistent with the results of our experimental study, where beveled cavities did not statistically influence the mechanical strength of the restorations.

However, there are also studies that have demonstrated the efficacy of the bevel design. In a recent study, Appel et al. (2021) show an elimination of the maximum tensile and compressive stresses at the level of composite restorations having a Cavo superficial bevel 1 mm wide [10]. In another study, Coelho-De-Souza et al. (2008) demon-

strate that a beveled MOD cavity has an advantage in terms of fracture resistance compared to a non-beveled MOD cavity restored with composite [11]. Additionally, Mondelli et al. (2019) observed a significant improvement in the fracture toughness of composite restorations, and a decrease in catastrophic fractures when beveling [12]. Furthermore, other studies conducted on marginal beveling of proximal box cavities have shown a considerable reduction in enamel fractures [8,13-15].

In these previous studies, the beveled cavities were restored by using a composite. However, composite restorations in temporary teeth have exhibited high failure rates. This is primarily due to the development of secondary caries. Thus, the use of GIC in temporary teeth is more advantageous compared to other products. Several laboratory studies have indicated that GIC-EQUIA Forte® Fil could compete with composite resins and RM-GIC- [5,16-18].

Since GIC-EQUIA Forte® is widely recommended in pediatric dentistry, it would be interesting to test its fracture resistance in proximal Cavo superficial bevel cavities. The results of the statistical analysis of this study did not reveal a significant difference in favor of beveled samples. When vertical force is applied to restorations using the YLE Universal Testing Machine restorations, tensile, compressive, and tensile stresses occur.

When vertical force is applied to restorations, it creates stresses between the enamel and the restorative product due to differences in their elasticity and mechanical properties [10]. Modifying the cavity structure reduces stress dispersion at the cavity walls and improves force distribution.

Type of fracture

According to Meurer et al. (2020), beveling the cavo superficial angle increases the exposure angles between enamel prisms and restorative material [19]. This aligns with previous research showing that the orientation of enamel prisms affects the strength of restorations. Carvalho et al. (2000) demonstrated that when enamel prisms are perpendicular to the restorative product, it improves tensile strength [9]. Therefore, incorporating a bevel has the potential to enhance strength. Our study supports this, as we primally observed adhesive fractures in the non-beveled samples (Figure 2a).

In contrast, Lynch et al. (2011) found that enamel is most vulnerable to fragility when forces are applied parallel to the prism orientation plane [20]. Similarly, Soliman et al. (2016) observed enamel fractures occurring laterally at the edges of restorations in samples where aprismatic enamel was not removed [8]. This pattern is also evident in our study, as we observed enamel fractures in the unbeveled samples (Figure 2b).

The beveling procedure effectively removed the fragile and mechanically weak aprismatic enamel layer.[7] Additionally, the bevel significantly reduced the occurrence of catastrophic fractures. Mondelli et al. (2018) noted a tendency towards oblique fractures rather than longitudinal (catastrophic) fractures in the beveled samples [12], which aligns with our own study results (Figure 3).

Furthermore, beveling the cavo superficial angle increased the contact area between the restorative product and the exposed enamel surface, improving its adhesion to the tooth. In our study, we observed more cohesive fractures than mixed fractures in the beveled group. Existing literature provides information on the influence of beveling on the type of fracture. Coelho-De-Souza et al. (2008) demonstrated in their study that thermocycling promotes adhesive failures at the interface due to the dissolution effect of hybrid layers and uncaptured collagen by the adhesives used [11]. The bevel design played a crucial role in protecting against adhesive failures at the interface of GIC-EQUIA Forte®. As a result, fractures were predominantly observed in areas distant from the bevel (Figure 4).

Limitations

The desired effect of the bevel is not entirely evident, possibly due to several limitations. Firstly, the study had a limited number of samples. Additionally, the manual preparation of standard-sized cavities resulted in slight variations in cavity dimensions. Furthermore, the Class II cavities with and without a bevel were prepared on different teeth, which introduces a potential bias in terms of tooth quality. Lastly, the force measurements obtained from the Universal Testing Machine may not fully represent the actual masticatory forces, which have a continuous amplitude and longer duration.

However, despite these limitations, it is still possible to observe the influence of the bevel on the type of fracture. In order to optimize the results of the current study, cavity design should ideally be standardized, and operators may consider using an oscillating cavishape file attached to a contra-angle handpiece for precise beveling of the Cavo superficial angles.

Furthermore, there is a growing practice of utilizing wider bevels to improve restoration retention. Practically no study has evaluated the role of the bevel in the fracture resistance of proximal restorations with GIC-EQUIA Forte®. Therefore, it would be beneficial to re-evaluate the results of this in vitro study through clinical research involving a larger sample size to validate these observations.

This in vitro study provides valuable insights into the external validity of the findings, offering pediatric dentists enhanced knowledge regarding cavity design for improved clinical outcomes.

Conclusion

Based on the results of this experimental study, it was found that modifying the Cavo superficial angle of Class II cavities by adding a bevel did not influence the fracture resistance of GIC-EQUIA Forte® restorations. This supports the null hypothesis and is consistent with previous studies that have shown that beveling is not beneficial in large Class II box cavities where the residual enamel is already weak. However, other studies have shown that beveling can improve the fracture toughness of composite restorations and reduce enamel fractures. It is worth noting that the present study used GIC-EQUIA Forte®, which is widely recommended in pediatric dentistry, as a restoration material in temporary teeth. GIC is more advantageous in temporary teeth than composite resins, due to its high resistance to secondary caries. In conclusion, the bevel design may not be necessary to improve the fracture resistance of GIC-EQUIA Forte® restorations in Class II cavities.

Acknowledgments

The experiment was performed at the Saint Joseph university in Beirut, Lebanon. We are thankful for the provision of the lab facilities to conduct this study, and we are also grateful for everyone who provided logistical assistance.

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