eISSN 2255-0569

ORIGINAL

Comparing the veneer shear bond strength to the enamel labial surface according to the occlusal-gingival level and cutting depth (an in vitro study)

Comparación de la resistencia a la cizalladura de la carilla a la superficie labial del esmalte en función del nivel oclusal-gingival y de la profundidad de corte (estudio in vitro).

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Received: 29 - XII - 2023
Accepted: 20 - I - 2024

doi: 10.3306/AJHS.2024.39.03.81

Abstract

Background and objectives: Veneer restoration success depends on tooth surface, thickness, cement, and preparation. Preserving tooth structure is vital to avoid debonding and ensure a good prognosis. This study aims to explore the shear bond strength of veneers based on the occlusal-gingival level and cutting depth of the enamel labial surface, comparing their success rates.

Methods: This in vitro study, conducted at Sulaymaniyah's Shorsh Dental Teaching Hospital from February to November 2023, involved the classification of thirty upper premolars into three groups. These thirty premolars were further distributed across three groups, each consisting of 10 teeth. Each tooth was partitioned into occlusal and gingival halves for bonding purposes. In Group 1, diamond bur grinding was performed, Group 2 utilized 0.5 mm depth guide burs with smoothing, and Group 3 employed 1 mm depth guide burs with smoothing. Subsequently, 10% zirconia-reinforced lithium silicate blocks were bonded to the teeth, and the shear bond strength was assessed after cementation and thermocycling.

Results: The study compared values between the occlusal and gingival halves within the three groups. Statistically significant differences were identified in Group 2 (P<0.05), where the highest mean in G2O was 25.25, indicating noteworthy variations between the occlusal and gingival subgroups. However, no statistically significant differences were observed in Group 1 and Group 3 (P>0.05). The mean for the occlusal halves was 17.5 for G1 and 19.0 for G3, while the means for the gingival halves were recorded as 12.0 for G1 and 13.0 for G3. The most substantial mean difference in bond strength related to cutting depth on occlusal halves was observed when comparing G2 to G1, with a difference of 7.75. Conversely, the lowest mean difference was noted on the gingival halves of G3 and G1, which was 1. An analysis of failure modes revealed that 9 out of 10 teeth in G1G, G1O, and G2O exhibited adhesive ceramic failure, constituting approximately 15%. Group 3 displayed the highest occurrence of adhesive tooth failure in the gingival half, with 6 teeth showing this failure in G3G, accounting for about 10%.

Conclusion: The shear bond strength of veneers is notably influenced by both the cutting depth and the location of the preparation, whether it is at the occlusal or gingival region. This influence on shear bond strength can exert a substantial impact on the overall treatment outcome.

Key words: Dental Bonding, Enamel Thickness, Preparation Depth, Shear Bond Strength, Veneers.

Resumen

Antecedentes y objetivos: El éxito de la restauración con carillas depende de la superficie dental, el grosor, el cemento y la preparación. Preservar la estructura dental es vital para evitar la descementación y garantizar un buen pronóstico. Este estudio pretende explorar la fuerza de adhesión al cizallamiento de las carillas en función del nivel oclusal-gingival y la profundidad de corte de la superficie labial del esmalte, comparando sus tasas de éxito.

Métodos: Este estudio in vitro, realizado en el Shorsh Dental Teaching Hospital de Sulaymaniyah entre febrero y noviembre de 2023, consistió en la clasificación de treinta premolares superiores en tres grupos. Estos treinta premolares se distribuyeron a su vez en tres grupos, cada uno de los cuales constaba de 10 dientes. Cada diente se dividió en mitades oclusales y gingivales con fines de adhesión. En el Grupo 1 se realizó un tallado con fresa de diamante, en el Grupo 2 se utilizaron fresas guía de 0,5 mm de profundidad con alisado y en el Grupo 3 se emplearon fresas guía de 1 mm de profundidad con alisado. Posteriormente, se adhirieron a los dientes bloques de silicato de litio reforzados con zirconia al 10%, y se evaluó la resistencia de la adhesión al cizallamiento tras la cementación y el termociclado.

Resultados: El estudio comparó los valores entre las mitades oclusal y gingival dentro de los tres grupos. Se identificaron diferencias estadísticamente significativas en el Grupo 2 (P<0,05), donde la media más alta en G2O fue de 25,25, lo que indica variaciones notables entre los subgrupos oclusal y gingival. Sin embargo, no se observaron diferencias estadísticamente significativas en los Grupos 1 y 3 (P>0,05). La media de las mitades oclusales fue de 17,5 para el G1 y de 19,0 para el G3, mientras que las medias de las mitades gingivales se registraron como 12,0 para el G1 y 13,0 para el G3. La diferencia media más sustancial en la fuerza de adhesión relacionada con la profundidad de corte en las mitades oclusales se observó al comparar G2 con G1, con una diferencia de 7,75. Por el contrario, la diferencia media más baja se observó en G2 con G1. Por el contrario, la diferencia media más baja se observó en las mitades gingivales de G3 y G1, que fue de 1. Un análisis de los modos de fracaso reveló que 9 de cada 10 dientes de G1G, G1O y G2O presentaron fracaso de la cerámica adhesiva, lo que constituye aproximadamente el 15%. El grupo 3 mostró la mayor incidencia de fracaso adhesivo dental en la mitad gingival, con 6 dientes que mostraron este fracaso en G3G, lo que representa aproximadamente el 10%.

Conclusiones: La resistencia de adhesión al cizallamiento de las carillas está notablemente influenciada tanto por la profundidad de corte como por la ubicación de la preparación, ya sea en la región oclusal o gingival. Esta influencia en la fuerza de adhesión al cizallamiento puede ejercer un impacto sustancial en el resultado global del tratamiento.

Palabras clave: Adhesión dental, grosor del esmalte, profundidad de preparación, fuerza de adhesión al cizallamiento, carillas.

Cite as: Dilshad Ahmed BM, Al-Zahawi A. Comparing the veneer shear bond strength to the enamel labial surface according to the occlusal-gingival level and cutting depth (an in vitro study). *Academic Journal of Health Sciences 2024*; 39 (3):81-86
doi: 10.3306/AJHS.2024.39.03.81

Introduction

Patient demand is a paramount consideration for dentists, with a prevailing trend toward a preference for less invasive dental procedures. Minimally invasive dental treatments prioritize the improvement of aesthetics while concurrently minimizing the removal of tooth structures. In such treatments, the quantity of remaining enamel post-tooth preparation assumes a pivotal role in preserving the integrity of dental restorations[1].

A reliable bonding process yields several benefits, including high retention strength, a stable restoration, and reduced micro leakage. However, bonding to dentin has been reported to be more intricate and less dependable, primarily due to the heterogeneous nature of dentin[2]. This characteristic poses a significant challenge in establishing a robust connection between modern adhesives and dentin. The troublesome nature of dentin is exemplified by the deposition of hydroxyapatite on a mesh of collagen fibers with hydrophilicity[2].

The foundation of aesthetic dentistry rests on adhesion to dental structures, encompassing both enamel and dentin[3]. Collagen fibers play a pivotal role in dentin adhesion. Preserving these fibers from degradation allows them to form a micro-mechanical bond with adhesives, ensuring the maintenance of good dentin bonding. Despite advancements in bonding to dentin, many authors emphasize the continued importance of considering bonding to enamel during tooth preparation[4,5].

The depth of preparation is a critical factor that determines the proportion of enamel surface on the adhesive interface, constituting one of the most crucial elements influencing debonding and the maintenance of adequate bonding strength[6]. Previous studies have consistently demonstrated that the predictability and success of bonding procedures are positively correlated with a higher presence of enamel[7].

Easily obtained and highly stable, these terms are a description of a successful adhesion to enamel which has been reportedly identified in routine clinical procedures of twenty-first-century adhesive dentistry.

The length and orientation of enamel prisms also play a role in influencing the etching depth, thereby impacting the bonding strength. The depth, direction, and quantity of enamel prisms exhibit variations corresponding to the crown's occlusal-gingival level, potentially influencing the bond strength between the veneer and tooth structure[8,9].

Given the scarcity of studies in this domain, particularly within the Middle East, this investigation was deemed necessary to explore the relationship between shear bond strength of veneers and tooth structure concerning the occlusal-gingival surface at various depths.

Materials and methods

This research employed an experimental study design conducted between February 2023 and November 2023 in Sulaymaniyah, Shorsh dental teaching center. Thirty upper premolars extracted for orthodontic purposes were utilized in this study. Inclusion criteria for the selection of upper premolar teeth were established, requiring individuals to be between 14 and 25 years of age and their teeth to be free from cracks or defects. Any tooth falling outside of the specified age range or presenting significant structural problems was excluded from participation in the study.

In this study, thirty upper premolars extracted for orthodontic purposes were obtained from patients aged 14 to 25 years. Before experimentation, these teeth underwent examination to ensure the absence of cracks or defects, followed by cleaning to remove debris or remnant tissue. Subsequently, the teeth were stored in distal water. The samples were categorized into three groups, each consisting of ten teeth.

To prepare the specimens, selected teeth were embedded in cylinders of cold-cure acrylic blocks (Palaxtreme, Kulzer) with dimensions of 10 mm in diameter and 25 mm in height from the cementoenamel junction. The first group (G1) involved the grinding of intact teeth using a fine (red) cutting diamond bur (ecoline, E850-F018), applied to the surface once without exerting pressure. The second group (G2) had depth guide burs of 0.5 mm utilized on all buccal surfaces, followed by smoothing with fine-cutting diamond burs (ecoline, E850-F018). The third group (G3) underwent preparation with depth guide burs of 1 mm on all buccal surfaces, followed by smoothing with fine-cutting diamond burs (ecoline, E850-F018). All preparations were conducted using a surveyor with a handpiece turbine fixed to it under cooling water, positioned one mm above the cementoenamel junction, with the bur aligned parallel to the tooth's vertical long axis.

A standardized etching procedure was carried out on the labial surfaces of all specimens using 37% phosphoric acid (Spident, Fineetch) for 15 s, followed by thorough washing with water and drying with oil-free air pressure. Ivoclar Universal Bond was then applied to all etched surfaces. Sixty blocks of lithium silicate reinforced with 10% zirconia Celtra Duo (ZLS) LT A1C14 CEREC Dentsply were prepared for the ceramic specimens, polished, and fired according to the manufacturer's instructions. The fitting surfaces of all prepared ceramic blocks were etched with 10% hydrofluoric acid (FGM), cleaned, and dried. Saline (Bisco, Bis-silane) was applied to the fitting surfaces of the blocks.

Two prepared blocks were randomly selected for each tooth and bonded to the labial surface: one to the occlusal third and the other to the cervical third, using dual-curing

Figure 1: The shear bond strength test was conducted utilizing a universal tensile testing machine.

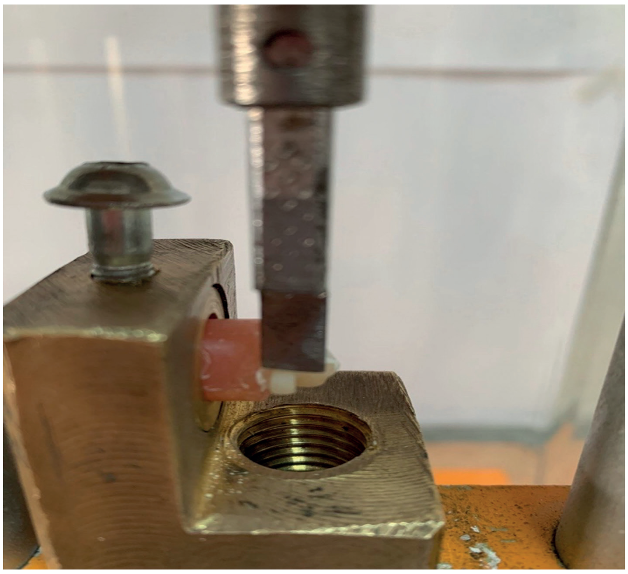
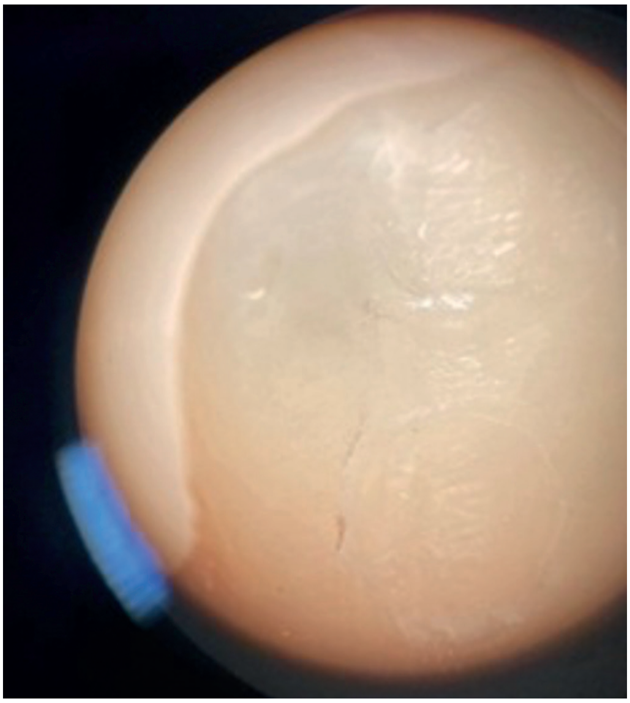


Figure 2: Adhesive tooth failure.



resin cement (Biscotti, duo-link). Cementation involved a 5 kg load application, with a light cure applied at the time of cementation and during the removal of excess material. The specimens were stored in distal water at room temperature for one week, followed by thermocycling (1500 cycles at 5 and 55°C with a dwell time of 30 s). Subsequently, all specimens underwent investigation to measure shear bond strength (SBS) using a chisel end-shaped metal with a 2 mm wide head attached to a universal tensile testing machine, operating at a speed of 1 mm/min until bond rupture As seen in **figure 1**.

Following the completion of the shear bond test, the collected specimens underwent detailed analysis to identify the specific failure modes. The results, as depicted in **figure 2** are categorized as follows: adhesive tooth resin cement, indicating debonding at the interface between the prepared tooth surface and resin cement; adhesive ZLS resin cement, characterized by debonding between the ceramic fitting surface and the prepared tooth surface; cohesive, involving internal fractures within the ZLS, tooth structure, or resin; mixed-tooth resin cement, reflecting failures in both the tooth structure and adhesive interface; and mixed ceramic, denoting failure at the adhesive interface of the ceramic surface.

Ethical approval for this study was obtained from the ethics committee (Kurdistan higher council) prior to the commencement of the research. The study was conducted in accordance with ethical guidelines and principles, ensuring the protection of participants' rights, confidentiality, and informed consent. All participants provided informed consent before their inclusion in the study.

The collected data were subjected to comprehensive statistical analysis. The normality distribution of the data was rigorously tested, and paired sample t-tests were employed to compare values between the occlusal half (O) and gingival half (G) of the groups. Additionally, one-way ANOVA revealed no significant differences among the three groups in both the incisal and gingival regions (P>0.05). Pearson's chi-square test was used to analyze the mode of failure.

Results

The comparison of occlusal half (O) and gingival half (G) values within the three groups was conducted through paired sample t-tests. The results demonstrated a notable distinction between the occlusal half (O) and gingival half (G) subgroups in Group 2 (P<0.05). Conversely, no statistically significant difference was identified between the occlusal half (O) and gingival half (G) subgroups in Groups 1 and 3 (P>0.05), as outlined in **table I**.

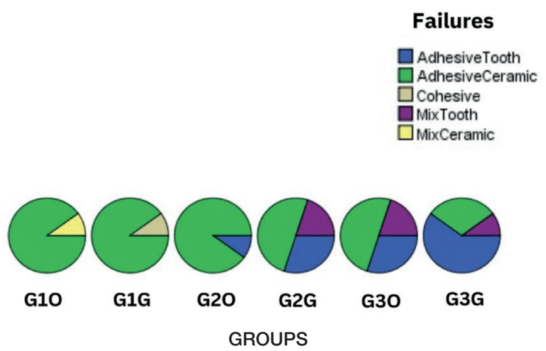
Table I: Assessing the bond strength in megapascal (MPa) based on the depth of tooth structure and its positional variation.

Groups	Subgroups	No.	Mean	St. Dev.	t	p value
Group 1	G1O G1G	10 10	17.5 12.0	11.18034 4.21637	1.575	0.150
Group 2	G2O G2G	10 10	25.25 15.50	12.71755 4.68449	2.954	0.016
Group 3	G3O G3G	10 10	19.0 13.0	6.99206 5.50252	1.695	0.124

The application of one-way ANOVA revealed a lack of statistically significant difference among the three groups in both the occlusal and gingival halves (P>0.05). Further analysis of the results indicated no significant disparities between the corresponding subgroups of Groups 1, 2, and 3 (G1O-G2O, G1O-G3O, G2O-G3O, G1G-G2G, G1G-G3G, and G2G-G3G), as outlined in **table II**.

The analysis of the mode of failure indicated a noteworthy association between the groups and the type of failure, established through the Pearson Chi-Square test (P=0.030). Notably, the G3G group displayed the highest frequency of adhesive tooth failure in comparison to the other groups. Specifically, the G1O group exclusively manifested instances of mixed ceramic failure, while cohesive failure was solely observed in the G1G group. These findings are detailed in **table III** and visually depicted in **figure 3**.

Figure 3: The bond mode failure.



Discussion

This study sought to investigate the influence of the preparation cutting depth and position within the tooth structure on the shear bond strength (SBS) of ZLS ceramics. Rigorous inclusion criteria were applied to select natural teeth to ensure standardization of the experimental setup.

Although both shear bond strength (SBS) and micro-tensile bond strength (μTBS) tests are frequently utilized for bond testing, micro-tensile bond strength testing is generally considered more reliable. However, in this particular study, the shear bond strength (SBS) test was chosen due to the anticipated higher occurrence of veneer failure, potentially induced by shear forces[6].

In this study, the etchable ZLS glass ceramic was employed, aiming to enable a minimally invasive design by bonding it to the tooth structure using resin cement[10]. This approach was chosen to facilitate the application of the ceramic in cases who waiting for orthodontic treatment was not feasible, particularly in addressing crowded teeth. Varying cutting depths have been explored to effectively accommodate the alignment of crowded teeth. Furthermore, the placement of the ceramic block on both the occlusal and gingival halves was designed to evaluate the impact of enamel type on bond strength, taking into consideration the prism direction and length[11]. Before undergoing testing procedures, the ZLS blocks were subjected to a 10-minute furnace treatment to enhance their strength to 370 MPa, following the manufacturer's instructions.

Table II: Assessing bond strength in relation to the cutting depth within the tooth structure.

Dependent Variable	Comparison	Groups	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
O	1	2	-7.75	4.73022	0.247	-19.4782	3.9782
		3	-1.5	4.73022	0.946	-13.2282	10.2282
	2	1	7.75	4.73022	0.247	-3.9782	19.4782
		3	6.25	4.73022	0.396	-5.4782	17.9782
	3	1	1.5	4.73022	0.946	-10.2282	13.2282
		2	-6.25	4.73022	0.396	-17.9782	5.4782
G	1	2	-3.5	2.16025	0.255	-8.8562	1.8562
		3	-1	2.16025	0.889	-6.3562	4.3562
	2	1	3.5	2.16025	0.255	-1.8562	8.8562
		3	2.5	2.16025	0.488	-2.8562	7.8562
	3	1	1	2.16025	0.889	-4.3562	6.3562
		2	-2.5	2.16025	0.488	-7.8562	2.8562

Table III: The mode of bond failure.

Groups	Failures					Total
	Adhesive Tooth	Adhesive Ceramic	Cohesive	Mix Tooth	Mix Ceramic	
	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
G3O	6 (10%)	3 (5%)	0 (0%)	1 (1.67%)	0 (0%)	10 (16.67%)
G3G	3 (5%)	5 (8.33%)	0 (0%)	2 (3.33%)	0 (0%)	10 (16.67%)
G2O	3 (5%)	5 (8.33%)	0 (0%)	2 (3.33%)	0 (0%)	10 (16.67%)
G2G	1 (1.67%)	9 (15%)	0 (0%)	0 (0%)	0 (0%)	10 (16.67%)
G1O	0 (0%)	9 (15%)	1 (1.67%)	0 (0%)	0 (0%)	10 (16.67%)
G1G	0 (0%)	9 (15%)	0	0 (0%)	1 (1.67%)	10 (16.67%)
Total	13 (21.67%)	40 (66.67%)	1 (1.67%)	5 (8.33%)	1 (1.67%)	60 (100%)

The results indicate that the attachment position of the ceramic block, whether towards the occlusal or gingival aspect of the tooth structure, influences the bond strength. Notably, a significant difference was observed between G2U and G2L, whereas no significant differences were observed between G1 and G3. This discrepancy may be attributed to the exposure of enamel prisms in the upper half of G2, as opposed to the lower half where cutting might have exposed more dentin structure[8].

Recent research has highlighted that the enamel thickness in the incisal portion of a tooth is 0.79mm, while it measures 0.56mm on the facial and palatal aspects. In the process of preparing ceramic veneers, it is common to expose dentin at the incisal edge, a phenomenon supported by existing literature[7,12]. These findings align with the outcomes of our study, particularly in the assessment of shear bond strength (SBS) in three distinct preparation groups.

Although achieving optimal aesthetic results may necessitate a more substantial reduction of tooth structure, this often leads to the unavoidable exposure of dentin[6,13]. It is widely acknowledged that bonding to enamel is vital for the long-term success of ceramic laminate veneers[7]. When veneers are primarily bonded to dentin, there is a high risk of failure[7,14,15].

The absence of a significant difference between the lower preparation locations for G1 and G3 may be attributed to the comprehensive bonding of both the upper and lower areas to the enamel in Group 1. In contrast, in Group 3, the bonding primarily involves the dentin area in both the occlusal and gingival halves.

The results of our study coincide with earlier research, illustrating the notable influence of preserving enamel on the shear bond strength (SBS) of ceramic laminate veneers[6].

In particular, a recent study highlighted the necessity for comprehensive infra-enamel preparation and the preservation of a minimum of 40% of enamel to attain optimal bond strength. Moreover, it is recommended that the preparation margins be situated in healthy enamel to enhance bonding strength and diminish the potential for secondary caries resulting from micro-leakage. These findings align consistently with our examination of SBS[6,16,17].

In the comparison of failure modes based on the preparation depth in the occlusal or gingival halves of the labial surface, no significant differences were observed across all groups. This lack of distinction may be attributed to the uniformity in cutting performed within the same structure, whether in the enamel of the occlusal half or proximal to the dentin layer of the gingival half. A study conducted by Nenand et al, reported that approximately 16.7% of cases exhibited exposed dentin at the cementoenamel junction[9].

The analysis of failure modes revealed a notable occurrence of adhesive failure at the ceramic-resin interface in groups G1O, G1G, and G2O. This is likely due to the robust bonding interface between the resin and enamel structure in these groups. In contrast, G3G exhibited the highest percentage of adhesive failure at the tooth-resin interface, possibly stemming from the exposed dentin in that area, resulting in a lower bond strength.

Acknowledging the study's limitations, it is clinically advisable to place all preparations in the enamel structure, as they may contribute to enhanced bonding and reduced adhesive failure.

Conclusions

In light of the study's limitations, it can be deduced that both the depth and location (occlusal or gingival) of the preparation significantly influence the bond strength of resin-bonded ceramics to the tooth structure.

Acknowledgments

Gratitude is extended to all individuals who have generously contributed their time, expertise, and efforts, thereby contributing to the successful completion of this study.

Conflict of interest

The authors declare no conflict of interest regarding the publication of this study.

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