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Influence of Tooth Preparation Geometry on the Fracture Strength of Direct Nano-Hybrid Composite Veneers: A Quasi-Experimental Analysis

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ABSTRACT

***Background*:** The longevity of direct composite veneers depends largely on the geometry of tooth preparation, which influences bonding surface, stress distribution, and resistance to fracture. Among common preparation designs, bevel and incisal overlap differ in enamel preservation and mechanical behavior. ***Objective*:** To compare the fracture strength of direct nano-hybrid composite veneers fabricated using bevel and incisal overlap preparation designs under in-vitro conditions. ***Materials and Methods*:** Eighty extracted human maxillary central incisors were randomly divided into two equal groups (n=40 each). Group A received bevel preparation, while Group B received incisal overlap preparation. All specimens were restored with nano-hybrid composite resin (CLEARFIL AP-X Esthetic) following standard etching and bonding procedures and subsequently thermocycle (300 cycles, 5–55°C). Each sample was loaded to failure in a universal testing machine at 45° to the long axis, and fracture strength (N) was recorded. Data were analyzed using an unpaired *t*-test ($p<0.05$). ***Results*:** The mean fracture strength of bevel-prepared veneers was 475.8 ± 47.3 N, significantly higher than that of incisal overlap-prepared veneers **(**287.6 ± 24.7 N**,** $p<0.001$). The bevel group exhibited a wider strength range (354–550 N) compared to the incisal overlap group (252–340 N). ***Conclusion*:** The bevel preparation design provides superior fracture resistance compared to the incisal overlap design in direct nano-hybrid composite veneers. This may be attributed to enhanced enamel bonding and more favorable stress distribution. Bevel preparation should therefore be considered the preferred technique for anterior composite restorations requiring strength and longevity.

Keywords: Fracture strength; Direct composite veneer; Bevel preparation; Incisal overlap; Nano-hybrid composite; Adhesive dentistry; Tooth preparation design; In-vitro study

INTRODUCTION

Traumatic injuries resulting in fractures of maxillary incisors are common clinical occurrences and present significant restorative challenges in aesthetic dentistry (1). With the evolution of adhesive systems and composite technologies, direct composite veneers have become a viable, minimally invasive treatment option for restoring fractured or discolored anterior teeth (2,3). Among restorative materials, nano-hybrid composites combine superior mechanical properties, optical behavior, and polish ability, allowing for both functional and aesthetic rehabilitation (4).

However, the long-term performance and fracture strength of direct composite veneers largely depend on the underlying tooth preparation geometry, marginal design, and bonding interface (5). Tooth preparation not only dictates the distribution of functional stresses but also influences the adhesion and mechanical endurance of the restoration (6). In this context, bevel and incisal overlap preparation techniques represent two commonly practiced designs that vary in extent, enamel exposure, and stress distribution.

The bevel preparation technique provides enhanced enamel bonding through increased surface area and removal of the aprismatic enamel layer, potentially improving marginal integrity and load resistance (7). Conversely, the incisal overlap preparation design allows for a broader bonding surface extending palatally, theoretically distributing stress more uniformly under occlusal load (8). Despite these theoretical advantages, comparative data on their influence over fracture strength in direct composite veneers remain limited.

Therefore, this quasi-experimental in vitro study aims to compare the fracture strength of direct nano-hybrid composite veneers fabricated using bevel and incisal overlap tooth preparation designs. The findings are expected to clarify the mechanical implications of preparation geometry on restoration performance and contribute to optimizing conservative aesthetic restorative techniques.

LITERATURE REVIEW

Aesthetic dentistry has evolved considerably, with growing emphasis on conservative restorative techniques that preserve natural tooth structure while ensuring mechanical durability. Among these, direct and indirect veneers have become integral to modern restorative practice due to their aesthetic and functional performance. However, the fracture strength of these restorations remains a critical determinant of long-term clinical success (1).

Several in-vitro and clinical studies have examined the impact of preparation design, restorative material, and bonding system on fracture resistance. In a comparative study, Nurla et al. (2019) evaluated four different veneer preparation techniques: window, feather, bevel, and incisal overlap and reported significant variations in fracture strength across groups. The highest mean value was observed in the control group (273.33 ± 81.01 N), followed by bevel (193.80 ± 66.59 N) and incisal overlap (188.93 ± 76.14 N), while window preparation exhibited the lowest (147.74 ± 48.95 N) (8). These findings suggest that preparation geometry directly influences the mechanical performance of composite veneers.

Gresnigt et al. (2021) compared the fracture strength of partial laminate veneers (PLV), conventional laminate veneers (CLV), and direct composite resin restorations (DCR) under aging conditions. Their results demonstrated that partial laminate veneers could achieve fracture resistance comparable to that of ceramic veneers and direct composites, with all groups showing clinically acceptable values after thermocycling. Moreover, the minor cracks observed in the aged samples did not compromise the overall fracture strength, indicating the structural stability of these restorative materials (9).

Similarly, Coelho-de-Souza et al. (2010) assessed the effect of adhesive systems and cavity margin geometry on the fracture strength of restored premolars. Using ANOVA and Tukey's tests, the study revealed that bevel preparation in conjunction with a total-etch adhesive system significantly enhanced fracture resistance compared to unprepared or unrestored teeth ($p < 0.05$). Importantly, the restored teeth regained strength values comparable to intact teeth, emphasizing the role of marginal configuration and adhesive selection in improving load-bearing capacity (10).

Collectively, these studies underscore the mechanical implications of preparation geometry and adhesive protocol on the fracture behavior of composite restorations. However, there is limited evidence directly comparing bevel and incisal overlap designs in direct nano-hybrid composite veneers, justifying further in vitro investigation to establish the optimal preparation technique for maximizing fracture strength and clinical longevity.

MATERIALS AND METHODS

***Variables**:* The study identified *fracture strength* as a primary dependent variable (11). It was defined operationally as the maximum stress or load that a material can endure before catastrophic failure occurs due to fracture. This property reflects the material's resistance to crack propagation and ultimate failure under applied load. The final recorded value before structural breakdown was designated as the *fracture strength* (12).

***Fracture Test**:* The experimental evaluation of fracture strength was performed using a standardized in-vitro testing procedure. Each restored maxillary central incisor was embedded in self-cure acrylic resin, maintaining a 2 mm clearance below the cemento-enamel junction to simulate alveolar support. The specimens were mounted in a universal testing machine at a 45° inclination to reproduce physiological incisal loading conditions. A compressive force was applied to the palatal surface of the incisal third at a crosshead speed of 1 mm/min until structural failure occurred. The peak load at fracture was recorded in Newtons (N) using digital force measurement software and processed in Microsoft Excel (13).

Statistical Analysis: Data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 26). The *student's t-test* was employed to compare mean fracture strength values between the two preparation designs (bevel and incisal overlap). Differences in fracture pattern distribution were evaluated using the *Chi-square test*. A significance level of $p < 0.05$ was adopted for all analyses (14).

Quality Assurance: To ensure methodological reliability, all fracture strength assessments were conducted following standardized testing protocols. Equipment calibration and consistent loading conditions were maintained across all samples to minimize variability (15).

Experimental Flow: The overall procedure involved specimen preparation, veneer fabrication, thermocycling, and mechanical testing. Fracture strength and failure patterns were measured using a universal testing machine (crosshead speed 1 mm/min) and examined under a stereomicroscope at 40× magnification. The mean fracture strength and corresponding fracture patterns were calculated and compared between preparation designs (16,17).

RESULTS

The gender composition of the patients revealed a nearly balanced representation between males and females. As illustrated in Figure 1, 54% of the respondents were male, while 46% were female. This distribution indicates a slightly higher proportion of male participants within the study population. The calculated male-to-female ratio was approximately **1:0.85**, suggesting that for every male participant, there were about 0.85 female participants. Such proportional representation ensures that both genders are adequately included in the analysis, minimizing the likelihood of gender-related bias in the interpretation of results. The balance between male and female participants also supports the generalizability of the study's findings regarding fracture strength variations across the tested groups.

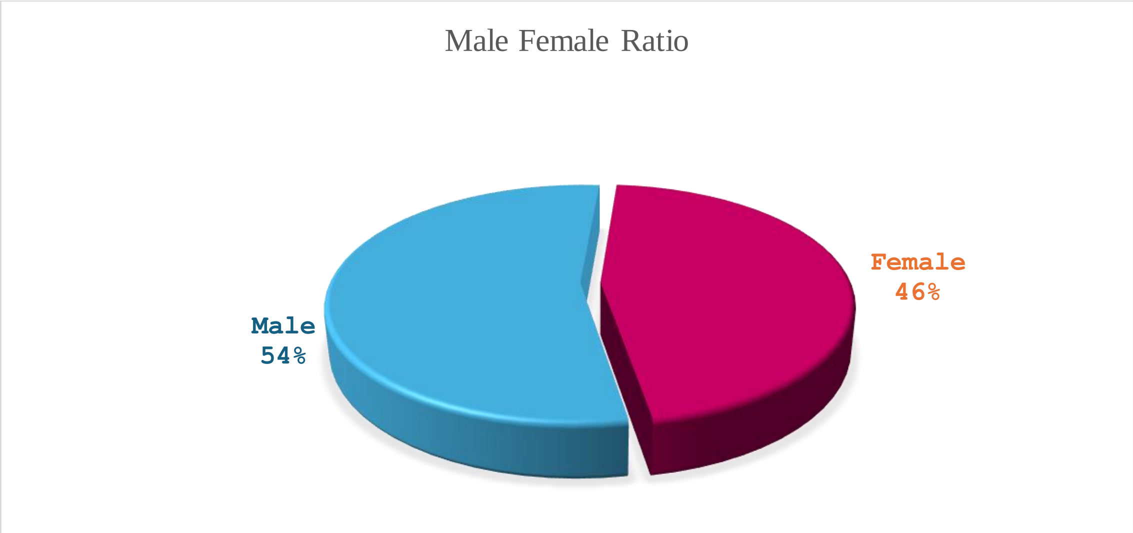

Figure 1: Gender distribution by percentage among the patients

Table 1 illustrates the range of recorded fracture strength values for the two tooth preparation designs. Specimens restored with the bevel design (Group A) exhibited substantially higher minimum and maximum fracture loads (354–550 N) compared to those with the incisal overlap design (Group B) (252–340 N). These results indicate that the bevel preparation provided greater resistance to fracture, reflecting improved structural reinforcement and load-bearing capacity of the restoration.

Table 1: Minimum and Maximum Fracture Strength Values for Bevel and Incisal Overlap Preparation Designs

Group	**Parameter**	**n**	**Min (N)**	**Max (N)**
A	Bevel	40	354	550
B	Incisal Overlap	40	252	340

The independent t-test was used to compare the measured fracture strength between the two preparation designs. The mean fracture strength of the bevel design (Group A) was 475.8 ± 47.3 N, while the incisal overlap design (Group B) recorded 287.6 ± 24.7 N. The difference between the two groups was found to be statistically significant (p < 0.001), indicating that the bevel preparation demonstrated superior load-bearing capacity and resistance to fracture.

Table 2: Comparison of fracture strength between Group A and Group B (n=80)

Parameter	**Group A** (Bevel, n=40) Mean±SD	**Group B** (Incisal Overlap, n=40) Mean±SD	***p*-value**
Fracture strength	475.8±47.3	287.6±24.7	<0.001*

Parameter	Group A (Bevel, n=40) Mean±SD	Group B (Incisal Overlap, n=40) Mean±SD	*p*-value
Newton	354-550	252.3-340	

p-value obtained by Unpaired t-test, $p<0.05$ was considered as a level of *significant

Table 2 shows that specimens restored using the bevel preparation exhibited significantly higher fracture strength compared to those prepared with the incisal overlap design. This finding confirms that the bevel configuration enhances structural integrity and provides greater resistance to fracture under applied occlusal loads.

DISCUSSION

This study investigated the influence of two different tooth preparation designsvbevel and incisal overlap, on the fracture strength of direct nano-hybrid composite veneers. The findings demonstrated a clear and statistically significant difference in fracture resistance between the two preparation geometries.

The mean fracture strength recorded for the bevel design (Group A) was 475.8 ± 47.3 N, while the incisal overlap design (Group B) exhibited a lower mean value of 287.6 ± 24.7 N. Statistical analysis using an independent t-test confirmed that this difference was highly significant ($p < 0.001$), indicating that the bevel preparation provided superior load-bearing capacity and resistance to failure under simulated occlusal stresses. The minimum and maximum fracture loads further reinforced this finding, with the bevel group demonstrating a broader and higher strength range (354–550 N) compared to the incisal overlap group (252–340 N).

The enhanced fracture resistance observed in the bevel design can be attributed to the increased enamel surface area available for bonding and the removal of the aprismatic enamel layer, which promotes stronger micromechanical interlocking with adhesive resins. This preparation also facilitates better stress distribution along the tooth–restoration interface, reducing localized tensile forces that often initiate cracks (18,19). In contrast, the incisal overlap design extends onto the palatal surface, potentially creating stress concentration zones and a less favorable distribution of occlusal loads, which may explain its comparatively lower fracture resistance (20).

The present results are consistent with those of Narula et al. (2019), who reported that direct composite veneers with bevel preparation exhibited higher mean fracture strength than other preparation types (21). Similarly, Khaliq and Alrawi (2014) observed significantly improved fracture resistance in bevel-prepared laminate veneers, emphasizing the mechanical advantage conferred by enamel beveling (22). Furthermore, Coelho-de-Souza et al. (2010) found that incorporating a bevel in conjunction with total-etch adhesive systems significantly enhanced fracture strength compared to non-beveled margins (23).

From a clinical standpoint, the superior performance of bevel preparation suggests that it not only improves the mechanical stability of direct composite veneers but also maintains a conservative approach to tooth structure preservation. Beveling enhances marginal adaptation, aesthetic blending, and adhesive retention, all of which contribute to long-term success. Although incisal overlap preparation may offer aesthetic benefits and coverage for more extensive defects, its relatively lower fracture resistance indicates that it may not be ideal in situations where high masticatory stress is expected.

Overall, the findings affirm that preparation geometry plays a decisive role in determining the mechanical performance of composite veneers. The bevel design, by optimizing adhesion and minimizing stress concentration, provides a more durable and fracture-resistant restorative outcome.

CONCLUSION

In conclusion, this in-vitro study demonstrated that the geometry of tooth preparation plays a crucial role in determining the fracture strength of direct nano-hybrid composite veneers. Among the two tested designs, the bevel preparation exhibited significantly higher fracture resistance (475.8 ± 47.3 N) compared to the incisal overlap design (287.6 ± 24.7 N), with the difference being statistically significant ($p < 0.001$). The enhanced strength associated with the bevel design may be attributed to its increased enamel bonding area, improved marginal adaptation, and better stress distribution across the restoration interface. These findings indicate that the bevel preparation design provides superior structural integrity and durability, making it the preferred option for anterior composite veneer restorations. However, further long-term clinical studies are recommended to confirm these results under functional oral conditions.

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