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Comparison of Enamel Preparations - Bevel, Chamfer and Stair Step Chamfer on Fracture Resistance of Nano Filled Resin Composites Using Bulk Pack Technique - An In Vitro Study

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Abstract

AIM: To evaluate and compare the effect of enamel preparation designs bevel, chamfer and stair-step chamfer on the fracture resistance of nanocomposite.

METHODS: The sample group of this study consisted of 72 non-carious permanent maxillary central incisors. The sample is divided into four groups of 18 each. Group, I control Group II bevel preparation, Group III chamfer preparation, group IV stair step chamfer preparation. After the specific preparation, each tooth is filled with nanocomposite using bulk pack technique. The teeth were subjected to fracture resistance test under Universal testing machine and then were examined under a stereomicroscope to evaluate the type of bond failure. The results were subjected to statistical analysis.

RESULTS: Results of the One-Way ANOVA revealed a significant difference in the mean peak failure load values of the four different groups. ($P < 0.001$) Tukey's Post-Hoc comparison test revealed that there was a significant difference in the mean peak failure load values of the bevel and chamfer preparation. But there was no significant difference between chamfer and stair-step chamfer preparation designs.

CONCLUSION: Stair-step chamfer preparation demonstrated comparable values to Chamfer preparation but also involved the removal of less amount of tooth structure adjacent to the fractured edge and good esthetic technique.

Introduction

The overall seriousness of traumatic injuries to the anterior teeth often focuses on the aesthetic implications of the injury. It is estimated that 1 out of every 4 persons under the age of 18 years sustains a traumatic dental injury in the form of an anterior crown fracture [1]. Eighty percent of the traumatised teeth were maxillary central incisors. The most common type of injury was a crown fracture involving both enamel and dentin (45.7%) [2].

The treatment of crown fractures of anterior teeth ranges from simple composite restorations to intracoronal gold inlay restoration. Ultimate treatment depends upon the severity of fracture of hard tissue. Such options end up with the removal of healthy tooth tissue to gain adequate mechanical retention [3] but also are time consuming and expensive. They are also contraindicated in the adolescents because of the large pulp chambers and continuous migration of the epithelial attachment [4]. Fragment reattachment of the crown is a widely accepted procedure in young adolescents, but it is seldom the parents or child realises the importance of retrieving fractured fragment, which is lost [5].

To achieve esthetics, fracture resistance and durability poses great difficulty in restoring class IV cavity of anterior teeth in the young patient. Shortcomings of restorative techniques developed until now are retention and esthetics [6]. From the discovery of acid etching technique to till the recent development in adhesive dentistry, the emphasis is mainly given on bonding to the enamel which reestablishes the integrity and strength to the restorative tooth complex [7].

Nano filled composite may represent an important milestone in this development which shows easy adaptation, high fracture resistance; excellent handling properties, outstanding polishability, long term colour stability and highly aesthetic properties make them use both anterior and posterior restorations [8].

Preparations techniques like featheredge were used earlier to prevent insult to the injured tooth, but they were weak, un-aesthetic due to over contoured margins. They were prone to marginal leakage and easy dislodgement. As a result, enamel reduction was considered necessary not only to accommodate the bulk of resin but also to increase the enamel surface area available for acid etching. The degree of retention varies directly with the amount of enamel available for acid etching. Enamel preparation also resulted in grinding of the superficial aprismatic layer by exposing the prismatic subsurface enamel before acid etching and thus has been strongly recommended [9].

In 1996, Albers introduced the stair-step chamfer preparation for class IV restorations he describes this preparation design as a chamfer that follows the vertical and horizontal anatomical contours, making the preparation look like stair steps at the same time masking margins by placing them within natural developmental grooves in the enamel of anterior teeth.[10] Such technique achieves high degree esthetics along with exposure of reactive enamel.

The purpose of this study is to determine the influence of enamel preparation designs namely bevel, chamfer and newly introduced stair-step chamfer on fracture resistance of nanocomposite resin (Filtek TM Supreme XT) restoration of standardised simulated incisal angle fracture in anterior teeth and the strength of interface between composite and tooth structure with the null hypothesis that there is no significant difference among the enamel preparation designs on fracture resistance of nanocomposite resin restoration of anterior teeth.

Methods

Seventy-two human, non-carious permanent maxillary central incisors were collected and stored in distilled water; the adherent blood and soft tissue were removed immediately after procurement. Then they were stored in 0.5% Chloramine-T bacteriostatic/bactericidal solution for one week. Following which, they were stored in distilled water at a temperature of 4°C [11]. To reduce deterioration, the storage medium was replaced each fortnightly. All teeth selected for testing were used within one month of procurement. An ethical committee approval was obtained to use extracted human teeth for the study.

All samples were mounted similarly for standardisation. PVC pipe tubes measuring the length of 2.5 cm, with a diameter of 2 cm were used to mount the teeth. During the mounting procedure, the cervical line of each tooth was made to coincide with the level of acrylic resin or upper edge of the tube to achieve parallelism and standard inclination of the incisal edges. The tooth should be at 90° to the upper edge of the tube. The roots of mounted teeth were subsequently embedded in cold-cure acrylic resin by dough method.

Individual custom-made strip crowns were fabricated on type III dental stone models using Biostar® machine (Essix technologies).

The specimens were divided into six groups of twelve samples each and colour-coded with coloured adhesive tapes and numbered. A standardised mesio-incisal fracture was created which coincides with 5 mm gingivally and 5 mm distally along the incisal edge. Then they were joined to form a base of an imaginary triangle with apex corresponding to mesio-incisal line angle.

Experimental fractures were made using low-speed diamond disc (JUNWEI, China) at a constant speed of 150 RPM. Using a standard diamond rotary bur (Mani Inc. Diamond bur TC-S21, ISO NO. 160/014), a 45° bevel extending 2 mm beyond the fractured incisal edge and through the entire enamel thickness, was given on the cavosurface margin of the tooth. Similarly with a standard diamond rotary bur (Mani Inc. Diamond bur SO-20, ISO NO. 288/012), a chamfer preparation and stair-step chamfer preparation was placed on the labial surface of teeth in their respective groups (Figure 1).

Figure 1: Different enamel preparation designs (Bevel, Stairstep Chamfer, Chamfer) on a typodont

The chamfer and stair-step chamfer included approximately half the thickness of the enamel and extended 2 mm cervically beyond the edge of the fractured surface. Stair-step chamfer was produced under the technique described by Harry F. Albers [10]. Lingually all preparations were restricted to an inclined bevel extending 2 mm cervically from the fractured edge. The enamel margins were acid etched with 35% phosphoric acid gel for 15 seconds, then thoroughly rinsed with water for 15 seconds.

Adper Single bond 2 Adhesive (3M ESPE, USA), a total-etch adhesive was applied on the prepared surface using adhesive applicator according to manufacturer's instruction and light-cured for 10 s using a quartz-tungsten-halogen light-curing unit (Optilux 501, Demetron; Danbury, CT, USA) with an irradiance of 500 mW/cm^2. All the preparations were restored with nano filled composite using custom strip crowns in bulk pack technique (Figure 2).

Figure 2: Completed restoration

After removing excess material, the resin composites were light-cured through strip crowns from labial and lingual sides. Strip crowns were removed gently with BP blade no. 15.

Specimens were aged for 24 hrs in distilled water at 37° degrees in an incubator and then subjected to cantilever bending test using a universal testing machine (Instron T-Series TINIUS OLSEN. Instron Corp. England, UK) to determine the resistance to fracture of composite restorations (Figure 5). A loading force was applied on a specific spot of lingual aspect of the specimen by 6-inch stainless steel rod with a 2.5 mm radius at a constant crosshead speed of 5mm per minute until the resin was dislodged or fractured. The readings were noted to determine the peak force at failure in Kilograms (Kg) then converted to Newtons (N).

Fracture mode evaluation

After the testing of preparations, the specimens were examined under a stereomicroscope at 40 x magnification to evaluate the type of bond failure.

The actual mode of failure was recorded according to the following criteria:

Adhesive (A): Failure at the tooth resin interface;

Cohesive (C): Complete failure within the resin restoration;

Mixed (M): Partial fractures of resin restoration and partial adhesive failure at the interface

Results

The null hypothesis states that there is no significant difference among the tested specimen

Table 1: Descriptive statistics of peak failure load (Newtons) for various groups mean, SD, SE

Groups	Mean	Standard Deviation	Standard Error
GROUP I (CONTROL)	610.63	37.55	11.87
GROUP II (BEVEL)	253.6	64.59	14.44
GROUP III (CHAMFER)	324.5	73.16	16.36
GROUP IV (STAIR STEP CHAMFER)	311.2	82.67	18.48

All the obtained data were subjected to statistical tests one way ANOVA test, Tukey's Post Hoc test and independent samples t-test. The mean peak failure load for control, bevel, chamfer & stair step chamfer preparations along with standard deviations values were observed as 610.63 ± 37.55, 253.6 ± 64.59, 324.5 ± 73.16 and 311.2 ± 82.67 in N respectively (Table 1) (Figure 3).

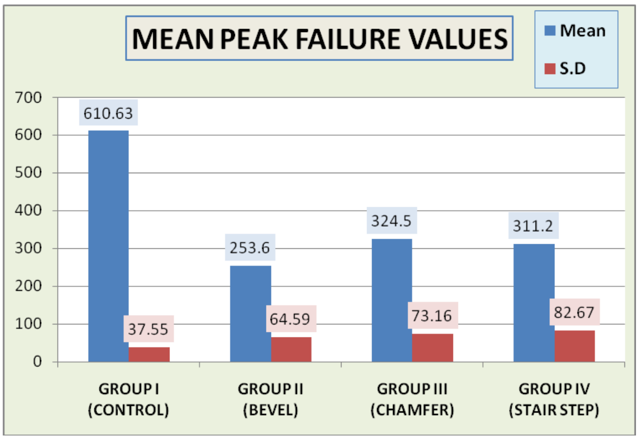

Figure 3: Mean Peak failure load values of various groups

One way ANOVA test revealed a significant difference in the mean peak failure load values of 4 different groups with an F value of 61.389 was found to be highly significant (P < 0.001). Tukey's Post Hoc test tests mean of various groups. Pairwise comparisons with control & test groups showed highly significant means. Multiple comparisons within test groups showed no significant differences in the mean peak failure load values, but there is a significant difference in the mean peak failure load between bevel & chamfer group.

Using Independent samples □t-test, the comparison of mean peak failure loads of bevel with chamfer & bevel with stair-step chamfer showed significant difference with 't' value of -3.248 (P < 0.001) & -2.455 (P < 0.05) whereas no significant difference between mean peak failure load of chamfer & stair step chamfer with 't' value 0.538 (P < 0.05), (Table 2).

Table 2: Descriptive statistics of peak failure load (Newtons) for Preparation groups along with the results of independent samples□t-test

GROUPS	MEAN (S.D)	't' test	p-value, Significance
GROUP II (BEVEL) GROUP III (CHAMFER)	253.6 (64.59) 324.5 (73.16)	-3.248	p < 0.001, highly significant
GROUP II (BEVEL) GROUP IV (STAIR STEP)	253.6 (64.59) 311.2 (82.67)	-2.455	p = 0.019 significant difference
GROUP III (CHAMFER) GROUP IV (STAIR STEP)	324.5 (73.16) 311.2 (82.67)	0.538	p = 0.593, no significant difference

Failure types examined under a stereomicroscope at 40 x magnification (Figure 4).

The bevel group (Group II) showed maximum mixed failure modes (50%) followed by adhesive (35%) and cohesive (15%) failure modes. The Chamfer group (Group III) showed a maximum of cohesive failure modes followed by mixed (35%) and adhesive failure modes (5%). The stair-step chamfer group (Group IV) showed a maximum of cohesive failure modes (55%) followed by mixed (35%) and adhesive failure modes (10%).

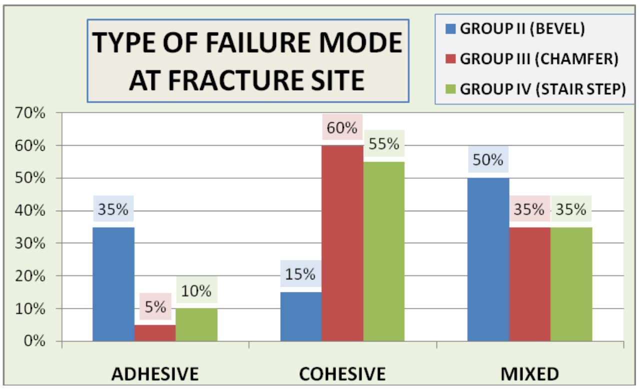

Figure 4: Percentage-wise distribution of failure modes in enamel preparation groups

Discussion

Resin composites are the material of choice for anterior esthetic restorations. The nanocomposite contains a unique combination of two types of nanofillers (5-75 nm) and nanoclusters. Nanocluster fillers are loosely bound agglomerates of nano-sized particles [8]. The combination of nanomer sized particles to the nanocluster formulations reduces the interstitial spacing of the filler particles. This provides for increased filler loading, better physical properties and improved polish retention [12]. The resin consists of three major components. TEGDMA is used in minor amounts to adjust the viscosity. UDMA and Bis-EMA resins are of higher molecular weight and therefore have fewer double bonds per unit of weight. The higher molecular weight of the resin results in less shrinkage reduced ageing and a slightly softer resin matrix.

However longevity of class IV restoration is not only dependent entirely on material, but cavity design is also utmost important for clinical success of such restorations. Various enamel preparation techniques, like butt joint margins, feather edge margins, bevels, chamfer preparation, short bevel and long bevel, have been recommended to achieve retention and esthetics [13]. The bevel design, given by Black, creates a gradual change of colour from the tooth to the restoration, but it is not as durable as a chamfer [10]. Jordan introduced chamfer preparation which enhances acid etching and provides increased marginal bulk which increases fracture and leakage resistance and higher retention of tooth structures [14]. Albers used the mamelons present on the labial surface of incisors in stair-step design by giving horizontal and vertical grooves with chamfer cavosurface margin to achieve good esthetic result [10]. As the strengths of restorative materials increases along with advances in adhesive systems, appropriate preparation designs on enamel for retention are persistently being evaluated.

Prevalence studies showed maxillary incisors most commonly involved in both types fractures, i.e. complicated and uncomplicated as well [15], [16]. Enamel preparation designs selected for this study are based on more esthetic outcome [10], availability of more reactive enamel surface to bond as there is the removal of aprismatic enamel [17], increase the bulk of restorative material [10].

Cantilever bending test was used to determine the fracture resistance of composite buildup.

Loading force was applied at a specific point on the lingual side of the restoration to simulate oral conditions.

In this study, obviously, the control group of untreated teeth showed significantly higher mean failure load values compared to the experimental groups (Highly significant; P < 0.001) (Table 1). The natural, intact teeth are more resistant to complex forces than restored teeth. Similar observations were made by the studies of Eid H [18], and Eid H, George EW [19].

Mean peak failure load for chamfer

preparation was higher than the mean peak failure load for bevel preparation. This difference is significant (Table 2). The bulk of composite at the margin is attributed to fracture resistance. This is by Donly KJ & Browning [20] and Kapil Gandhi [21]. Though the mean peak failure load for chamfer preparation was higher than stair step chamfer, the difference between these two groups was found to be insignificant. The probable explanation could be the removal of less tooth structure, specifically at the junction of horizontal and vertical margins.

The findings were in agreement with Kapil Gandhi [21] and were in disagreement with the findings of Hani Eid and White GE [19].

On the overall assessment of types of failures, cohesive type of failures was highest in chamfer and stair-step chamfer groups. It reveals that the complex forces applied during the loading process can cause fracture through the material itself rather than at the interface. More strengthened margins were present in these two preparation designs. Higher numbers of adhesive failures were observed in bevel group [Graph II]. This might be due to less contribution of bevel preparation design on the interfacial bond strength.

In conclusion, the combination of enamel preparation design and resin composites gives rise to better restorations. In our study, a chamfer preparation design has a high resistance to fracture than a bevel. Both the chamfer and stair-step chamfer preparation designs influence the fracture resistance of composite material. Stair-step chamfer will mask the finish lines within by natural visible markings in the enamel. On the other hand, it has a similar effect on fracture resistance of composite and similar failure modes as that of the chamfer. For further acceptability, more clinical trials should be carried out.

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