Original Article

The Effect of Fracture Pattern of Anterior Teeth on Fracture Strength of Silorane- Based and Nanohybrid Composite Restorations

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Abstract

Statement of problem: One of the most important concerns in choosing a treatment plan for a fractured anterior teeth is their fracture pattern. Selecting the best restorative material is crucial in restoration of them.

Objective(s): The present study was aimed to evaluate the effects of fracture pattern and the composite type on the fracture strength of fractured anterior maxillary teeth.

Materials and Methods: 40 sound maxillary anterior teeth were randomly divided into four groups of ten teeth (H1, H2, O1, and O2). In H1 and H2, the incisal edges were cut horizontally by 3mm below the incisal edge and in O1 and O2 the incisal edges were cut obliquely from the middle of incisal edge to 6mm below the incisal edge on the proximal side. A nanohybrid composite (Z350) was used for restoring the samples of H1 and O1 whilst a silorane-based composite (P90) was used in H2 and O2. Fracture strength was measured and the failure mode was recorded. Data were analyzed using one way analysis of variance (ANOVA) and Tamhane's post hoc tests. The level of significance was $p < 0.05$.

Results: Restoration with composite resin Z350 showed a higher strength in both cutting patterns ($p < 0.001$). Fracture strength was greater in horizontal pattern, regardless of the composite type used for restoration; however, the difference was not statistically significant for P90 ($p = 0.930$).

Conclusions: Fracture resistance of the fractured anterior teeth restored with Z350 is higher than that achieved with P90 for both fracture patterns.

Introduction

Dental trauma is extremely frequent during the pre-school and school years in children and young adults. According to the statistics, 33% of adults experience trauma to permanent teeth at least once in a lifetime [1]. Crown fracture is the most common complication of these injuries in permanent dentition [2]. Due to the protrusion and growth mechanism of maxillary anterior teeth in permanent dentition, they are more susceptible to trauma and crown fracture [3]. Damaged anterior teeth are highly demanded for early restoration both functionally and aesthetically to satisfy the patient's psychological and physical needs, particularly in young people [3].

Various factors such as fracture size, fracture pattern, crown reconstructability, presence of teeth fragments, aesthetic considerations, dentition stage, occlusion type, and pulp exposure affect the treatment plan for reconstruction of fractured tooth crown [4-5]. As mentioned, one of the most determining factors in choosing a treatment plan is the fracture pattern which is classified to the following four groups based on WHO classification; enamel fracture, crown fracture without pulp exposure, crown fracture with pulp exposure, and crown-root fracture [6].

To restore the tooth crown fracture without pulp exposure, dentists have applied many techniques so far, such as full ceramic crowns employing CAD/ CAM systems, crown reconstruction with composite resins and reattachment of teeth fragment [7-8]. Among the available favorable materials, composite resins with great developments in their material and application technique have become appropriate and reliable for different sorts of dental restoration and reconstruction of fractured teeth. A conservative and common treatment for uncomplicated crown fractures is composite resin restoration [8-9].

Nanohybrid composite resins, introduced in an endeavor to provide a material presenting high initial polishing, were produced with filler particles of 0.1-100 μm that improved the properties of composites such as wear resistance, knoop microhardness, and diagonal tensile strength [10]. Despite the recent developments in production of composite resin with desired mechanical and physical properties, polymerization contraction is still a major disadvantage of this material; which is 1.5-5 percent by volume in the present composite resins. Combining the benefits of both siloxane and oxirane, the silorane-based composite resins were produced to decrease the polymerization contraction [11]. Siloxane is the main body of silorane-based composite resin which results in the low polymerization shrinkage [12]. Because of the different polymerization mechanisms, manufactures have provided a specific adhesive bonding system for these composite resins [11].

Therefore, the current study was aimed to compare

Table 1: Materials used in this study

Material	Manufacturer	Type	Composition
Silorane adhesive system primer	3M ESPE, USA	Two-step self- etch acid primer	Phosphorylate methacrylates Vitrebond copolymer, Bis-GMA, HEMA, water/ethanol solvent, silane treated silica fillers
Silorane adhesive system bond	3M ESPE, USA	Two-step self-etch adhesive	Phosphorylate methacrylates, hydrophobic dimethacrylate, TEGDMA, silane treated silica fillers
Filtek P90	3M ESPE, USA	Silorane-based composite resin	Monomers:3,4- epoxycyclohexyl-ethyl-cyclo-poly-methylsiloxane (5-15% w/w), bis-3,4-epoxycyclohexyl- ethyl-phenyl-methylsilane (5-15%w/w)Fillers:SiO2, YtF3(55%v ,76%w)
Etchant 37%	Ivoclar Vivadent, Germany		H3PO4 37%
Adper single bond II	3M ESPE, USA	Two-step etch-and-rinse adhesive	
Filtek Z350	3M ESPE, USA	Methacrylate-based composite resin	Monomers: Bis- GMA, UDMA, TEGDMA, PEGDMA, bis-EMA Fillers: Zirconia/silica (63.3% v, 78.5% w)
Chloramine	Applichem, Germany	Disinfectant	Chloramine T trihydrate
Putty	Coltene	Impression material (Condensation-type) high consistency	Polysiloxane

the fracture strength of silorane-based and nanohybrid composite restorations and to determine a better and more resistant material in restoration of the fractured anterior teeth crown with respect to the different types of fracture patterns.

Mateirals and Methods

The materials used in this study are shown in Table 1. This experimental study recruited 40 extracted sound human maxillary central incisors free from calculus, crack, caries, restorations, and congenital defects with approximately similar anatomic crown dimensions measured by a caliper and a periodontal probe (mesiodistal width of 9 mm and length of 10 mm).

After removing any debris or soft tissue residues from the teeth, cleaning them by pumice paste and rubber cap, the teeth were disinfected with 1% chloramine T solution (Applichem; Germany) at 4°C for 7 days. Each tooth was mounted 1mm below the cement enamel junction (CEJ) in 2×2cm polymerizing acrylic resin (Acropars; Iran). The incisal edge was parallel to the horizontal plan. A putty (Coltene; Swiss) index was prepared as a guide for restoration of tooth crown (Figure 1).
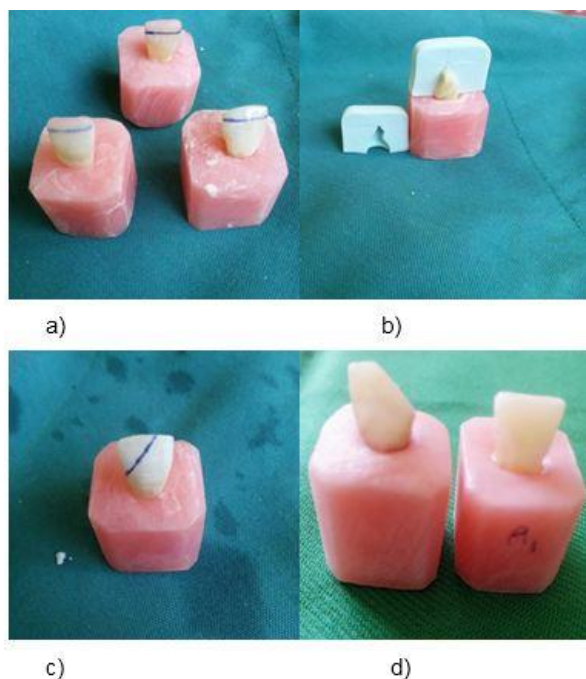
Figure 1a: Index of putty as a guide for restoration of tooth crown, **b:** oblique pattern reduction marked, **c:** Horizontal pattern reduction marked, **d:** oblique and horizontal pattern; with 0.5mm width bevel in enamel margin(d)

The specimens were randomly divided into two groups (n=20). In order to obtain horizontal and oblique sections (group H and O, respectively), the incisal edge of the teeth were sectioned by diamond discs (D & Z; Germany) under water coolant. Each disc was only used for 3 samples. The Specimens were prepared in the following method:

Horizontal group (H): the incisal edge of the teeth in this group was reduced by 3 mm below the incisal edge horizontal.

Oblique group (O): the incisal edge was reduced from the middle of incisal edge to 6mm below that, at proximal surface in oblique pattern.

Then the enamel margins of all samples received 45° bevel width of 0.5 using a diamond chamfer bur (Tizkavan; Iran).

The specimens in each group were randomly assigned to two subgroups (n=10) according to the type of composite resin:

Subgroup H1: the prepared surface was etched with 37% phosphoric acid (Ivoclar Vivadent; Germany) for 15 seconds, rinsed with water for 20 seconds and gently air-dried for 10 seconds from a distance of 20 cm, leaving the surface slightly moist. Two consecutive coat of Adper single bond II (3M ESPE; USA) were applied, gently air-dried and light–cured for 10 seconds by the light curing unit (Optilux 501, Demetron, Kerr), with a light intensity of 600 mW/cm^2. Nanohybrid composite Z350 (3M ESPE; USA) was then incrementally applied in two increments with the thickness of no more than 1.5 mm for each increment on the incisal edge and each increment was light cured for 40 seconds in the incisal direction. Finally, the initial putty index was used to confirm the propriety of length and width of the teeth.

Subgroup H2: the primer of silorane adhesive system (3M ESPE; USA) was applied on the dentin surface for 15 seconds, gently air-dried, and light-cured for 10 seconds. Then, the silorane system adhesive bond (3M ESPE, USA) was applied, gently air-dried, and light cured for 10 seconds. After that, Filtek silorane-based composite resin (P90) (3M ESPE; USA) was placed the same as subgroup H1.

Subgroup O1: the restoration process was performed as in subgroup H1.

Subgroup O2: all the stages of restoration were ca-

rried out as described in subgroup H2.

Then the teeth were subjected to 1000 thermal cycles (TC-300; Vafaee, Iran) at 5±2-55±2 °C in distilled water with both dwell time and transfer time of 30 seconds. The specimens were transferred to a universal testing machine (Z020; Zwick/Roell, Germany) to assess their fracture strength. The teeth were first fixed within the device horizontally, and then the force was applied using a ball (2mm in diameter) at 90° angle to the palatal surface at an area 1mm below the incisal edge until failure occurred [13]. The load required for fracture in each tooth was recorded in MPa. The mode of fracture for the four subgroups (adhesive, cohesive and mixed failures) was evaluated by a stereomicroscope (Carl Zeiss, Oberkochen, Germany) [14-16]. Statistical analysis of fracture strength was performed by using One-way ANOVA and Tamhane's post-hoc tests ($p < 0.05$).

Results

The Mean±SD values of fracture strength (MPa) of the 4 subgroups are summarized in Table 2 and Figure 2. According to the curves and columns, the highest and lowest mean fracture strength was observed in subgroup H1 and O2, respectively.

Table 2: The mean and standard deviation of fracture strength (MPa) of all groups.

Groups	Mean (MPa)	Standard deviation
H1	254.80	35.73
O1	168.60	37.64
H2	88.09	14.30
O2	82.10	14.09
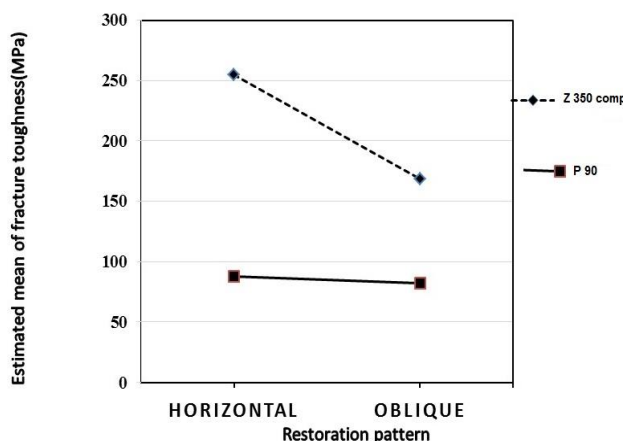
Figure 2: The mean fracture strength of the restored teeth

One-way ANOVA test revealed significant differences in fracture strength among the subgroups ($p < 0.001$).

To determine the difference between the two main groups, Tamhane's post-hoc test was used (Table 3). The mean fracture strength was significantly higher in subgroup H1 compared with the other three subgroups ($p < 0.001$). Moreover, the increase was statistically significant in O1 when compared with O2 and H2, respectively ($p < 0.001$). The mean fracture strength in H2 was higher than O2; however, the difference was not significant ($p = 0.930$) as demonstrated in Table 4. Analyzing the failure pattern revealed that adhesive failure at the interface of restoration and the tooth structure occurred in all the specimens in H2 and O2. Cohesive failure was observed to have occurred in dentin at the CEJ in three specimens of H1 and one of O1. The rest of specimens in this group experienced adhesive failure at the interface of restoration and the tooth structure.

Table 3: Tamhane's post-hoc test ($p < 0.05$) result of comparing all groups.

Subgroups	*p* value
H1 vs. O1	< 0.001
H1 vs. H2	< 0.001
H1 vs. O2	< 0.001
O1 vs. H2	< 0.001
O1 vs. O2	< 0.001
H2 vs. O2	0.930

H1: Z350-Horizontal pattern; H2: P90-Horizontal pattern; O1: Z350-Oblique pattern; O2: P90-Oblique pattern

Table 4: The mean and standard deviation frequency of fracture failure modes of specimens after being loaded (%)

Subgroups	Adhesive Failure	Cohesive Failure in Dentin	Cohesive Failure in Restoration
Z350-Horizontal	7(70%)	3(30%)	0(0%)
Z350-Oblique	9(90%)	1(10%)	0(0%)
P90-Horizontal	10(100%)	0(0%)	0(0%)
P90-Oblique	10(100%)	0(0%)	0(0%)

Discussion

The aim of this research was to investigate the fracture strength of two types of composite resins used to restore fractured maxillary anterior teeth with different fracture patterns. The strength of restoration required for achieving desirable results in intra-oral cavity has

not been fully studied. Studies concerned with the physical properties of composites have proven that composite restorations are generally fractured in the area where the composite comes into contact with the enamel [17].

Different methods have been investigated to improve fracture strength of anterior teeth restorations. One of them is using fiber for reinforcing the composite restoration [8]. It was shown that using fiber in central part of fracture anterior teeth significantly increased the strength of composite restorations [8]. In another study, the fracture strength of microhybrid, nanofill, and fiber-reinforced composites compared and detected that the last yielded a stronger restoration bond [18]. However, decreased aesthetic and the excessive need to reduce the tooth structure are always two limiting factors in using fibers. Therefore, using fiber has become limited to few cases [19].

One important factor which needs to be considered about bonding efficacy is some changes in the tooth structure associated with aging that leads to decrease the adhesion of restoration to the tooth structure [20]. In the present study, all samples were collected from middle-aged patients (35-50 years old) in order to create a degree of homogeneity between the samples. In this study, a diamond disk was used for sectioning the tooth crown, which can be considered among the limitations of this research since the cuts made can never be completely similar to the common tooth fracture. Also, the anatomy of the surface produced by the cut is clearly different from the surface resulting from a natural fracture [21].

In this study, the bond strength of the restorations to the tooth structure revealed significant statistical differences; the nanohybrid composite Z350 (mean=211.7 MPa) was superior to the silorane-based composite P90 (mean=85.1 MPa). This was compatible with the results of a study which showed that methacrylate-based resins (Z350) had higher bond strength than silorane-based composites (P90) [22]. In another study, 24 hours after restoration with these two types of composites, no significant difference was found between their bond strength to the etched enamel; however, 6 months later, composite Z350 showed better bond strength than P90 [23]. Adper single bond II is classified as a total-etch adhesive system while the P90 adhesive system is classified as a self-etch adhesive system. In the current research, one of the reasons that the bond strength of Z350 was more than P90 can be the difference in bonding systems used for each composite. In consistent with this study, Perdiago *et al.* reported that the total-etch adhesive had higher micro tensile bond strength than the self-etch adhesive [24].

The fractures that usually occur in the intra-oral environment are caused due to fatigue and propagation of small cracks under recurrent pressures as well as the impact forces that are the result of a sudden pressure from biting or chewing hard objects. Functional forces in oral cavity have different intensity, speed, and direction; however, in laboratory, the force is increased with fixed speed and direction until fracture occurs. Moreover, fixing the teeth so rigidly in experimental environment deprives them from the flexibility of periodontal ligament tissue around them which may lead to different fracture patterns [25]. Also, the type of maintenance environment also affects the mechanical properties of composites [26]. In this study, the samples were maintained in saline solution which is different from saliva. Also, the samples restored with P90 composite showed the fracture at the interface of restoration and tooth structure with lower occurrence of fractures compared to other groups. However, in some samples of the groups restored with nanohybrid Z350, fractures have occurred in CEJ region which indicates the higher bond strength between the tooth and composite. Thus, it seems that the type of composite and fracture pattern significantly affected the fracture strength and the mode of fracture.

Regarding the effect of tooth fracture pattern, the results of this study showed that for composite Z350, the restoration fracture strength would be higher if the fracture pattern was horizontal, but for composite P90 in similar situation, no statistically considerable difference was observed. According to the laws of the levers, in the case of a class-1 lever, the greater arm is the distance of the point where the force is exerted from the fulcrum, the smaller arm is the force required for lifting a weight placed in the opposite direction of the force. So the position at which the force is exerted on the tooth will be similar to the position at which the force is exerted on the lever, and the position of resto-

ration will be similar to the fulcrum in lever. There-fore, according to figure 1, it seems that a probable reason for such a situation to occur was the shorter distance of the position of the head of apparatus used to exert force on restoration from where the restoration comes into contact with the tooth structure. Since the length of the area which was the place of bonding between restoration and the tooth was equal, and also the place of applying the force was fixed and located at a distance of 1mm from the incisal edge, the distance of the place where the force was applied from the restoration surface in the oblique pattern was greater than the corresponding distance in the horizontal pattern. Thus, a lesser force was required to fracture the oblique pattern. In other words, the resistance of the horizontal pattern against fracture was higher than the oblique pattern. Additionally, the oblique pattern had sharp corners which caused the tension to be concentrated at these points. Increase in the concentration of tension raised the fracture potential, and in other word, caused the resistance of the oblique pattern to decrease [27]. According to the results of this study, type of composite resin may affect failure load.

Future investigations are suggested with different types of composite and adhesive systems in anterior and posterior teeth. Also, it must be noted that the results obtained in in vitro studies cannot be completely the same as those obtained in an in vivo experiment and more clinical studies are needed to investigate the results of this study.

Conclusion

Considering limitations of this in vitro study, it can be concluded that using nanohybrid composite resin Z350 in restoring the central maxillary teeth increases the fracture strength in both horizontal and oblique fracture patterns. Despite its low shrinkage contraction, the silorane-based composite P90 does not significantly increase the fracture strength of the restored central maxillary teeth in horizontal and oblique fracture pattern. Hence, Z350 nanohybrid composite resin might be a suitable material for restoration of incisor teeth with any fracture pattern.

Conflict of Interest: None declared.

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