DENTAL MEDICINE

Original Research

The influence of different types of bevels on the fracture resistance of directly restored lower anterior teeth

Mădălina Balaj[1], Simona Iacob[1,†], Marius Bud[2,†], Ada Delean[2], Mircea Cristian Dudescu[3], Smaranda Buduru[1]

1) Prosthetic Dentistry and Dental Materials Department, Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania

2) Conservative Odontology Department, Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania

3) Department of Mechanical Engineering, Faculty of Mechanical Engineering, Technical University, Cluj-Napoca, Romania

[†] These authors had equal contribution to the manuscript

Abstract

Background and aims. In recent years, dental trauma has been on the rise. The most common, regarding permanent dentition, are uncomplicated fractures (involving enamel or enamel and dentin) of the maxillary central incisors, followed by maxillary lateral incisors and mandibular central incisors. In anterior teeth, high impact stresses are frequently produced and because of this it is necessary that the restoration has a high fracture resistance. The aim of this study is to evaluate the influence of marginal cavity preparations (45° bevel and chamfer bevel) on the fracture resistance of teeth treated with direct composite resins.

Methods. For this study, 24 extracted mandibular incisors were used. All soft tissue debris and tartar were removed. During the study, the teeth were kept in saline to prevent dehydration. The teeth were divided into three groups of 8 teeth each. Group number 1 was used as a control and named C, in group number 2, named CH, incisors were prepared with a chamfer type of bevel, and in group number 3, named B45, incisors were prepared with a 45° bevel. After preparing all mandibular incisors, they were directly restored with nano-ceramic composite (Ceram.x® Duo, Dentsply Sirona). Subsequently, all three groups were fractured to determine the maximum compressive load using the Instron 3366 universal testing machine. To ensure a standardized fracturing process, all incisors were embedded in self-polymerizing acrylic resin up to the neck to replicate the conditions in the oral cavity.

Results. The Student's T-test was employed for statistical analysis, revealing a statistically insignificant difference between the CH and B45 groups. Nonetheless, it was noted that the average values of maximum compressive loads in the chamfer bevel group were higher compared to those in the 45° bevel group, indicating its superior resistance to fracture. Additionally, the results of the fracture resistance test demonstrated that intact mandibular incisors are three times more resistant to fracture than mandibular incisors prepared and restored with dental bevels.

Conclusion. Intact teeth present a superior fracture resistance compared to teeth that have been subjected to trauma or carious processes, requiring coronal restoration; dental restorations made with a chamfer bevel marginal preparation withstand higher forces with improved fracture resistance compared to those made with a 45° bevel marginal preparation.

Keywords: bevel, chamfer, fracture resistance, mandibular incisors, composite resins

DOI: 10.15386/mpr-2773

Manuscript received: 16.07.2024
Received in revised form: 09.08.2024
Accepted: 05.09.2024

Address for correspondence:
Marius Bud
mariusbud@mbdental.ro

Background and aims

In recent years, there has been a continuous rise in dental injuries, particularly among children and adolescents. The most frequent occurrences, affecting permanent teeth, are uncomplicated fractures (involving enamel or enamel and dentin) of the upper central incisors, followed by upper lateral incisors and lower central incisors [1-3]. Consequently, significant emphasis should be placed on appropriately restoring these lesions, prioritizing aesthetics.

There are various techniques available for restoring fractured anterior teeth. Among these, reattaching the fractured tooth fragment is highly recommended because it restores the tooth's original aesthetics, matches the dental wear of neighboring teeth, and provides fracture resistance similar to composite resin restoration [3-6]. However, the fractured tooth fragment may not always be retrievable, either due to loss during the trauma or improper storage leading to dehydration, or because too much time has elapsed since the trauma occurred and the patient visited the dental office. As an alternative, direct restorations using composite resins can be performed.

The superficial layer of enamel in 70% of permanent teeth contains aprismatic enamel, which offers considerably lower mechanical retention. Removing 0.1 mm of this enamel layer increases bond strength by up to 50%, depending on how much aprismatic enamel remains [7]. Unprepared enamel also contains higher levels of fluoride, making it resistant to acid. Previous studies have indicated that tooth fracture resistance decreases when preparing the tooth without a bevel, particularly with a cavosurface angle of 90° [8-11]. Therefore, minimal enamel preparation through a dental bevel is necessary. The most commonly used type is the 45° bevel, which preserves more dental structure while exposing the ends of enamel prisms [7]. The 45° bevel provides superior marginal sealing to the unprepared tooth, ensuring good aesthetics due to a subtle transition and gradual color change between enamel and composite. The concave (chamfer) bevel exposes the largest surface area of enamel prisms, offering the highest retention to dental structures. However, due to the greater removal of dental tissue during preparation, its use should be limited to situations where maximum retention from acid demineralization is necessary [7].

Considering all these factors, it remains uncertain to what extent the type of bevel influences the mechanical strength of teeth restored with composite. Additionally, the majority of studies have examined this strength in maxillary central incisors, with very few studies addressing fracture resistance in mandibular incisors, almost none being available [11].

The aim of this study is to assess the fracture resistance of lower anterior teeth that have been directly restored following preparation with different types of bevels. Two null hypotheses were tested:

1. Intact mandibular incisors do not demonstrate superior fracture resistance compared to prepared and filled mandibular incisors with bevels.
2. Mandibular incisors prepared and filled with a chamfer bevel do not show superior fracture resistance compared to mandibular incisors prepared and filled with a 45° bevel.

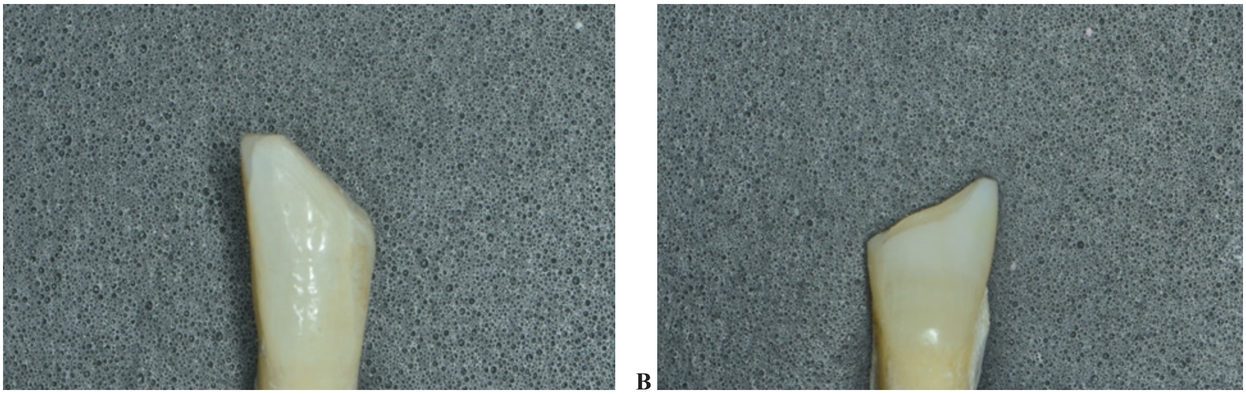
Methods

For this study, 24 extracted mandibular incisors were used. The study was approved by the Ethical Committee of the Iuliu Hatieganu University of Medicine and Pharmacy under reference number 99/20.03.2023. Before their utilization, all remnants of soft tissue and tartar were removed from the teeth with the help of an ultrasonic scaler. Selection criteria for the teeth included intact mandibular incisors and exclusion criteria encompassed the presence of dental fractures, non-carious wear lesions, dental tartar, and carious lesions due to their potential impact on reducing the fracture resistance of the respective tooth.

Throughout the study, the teeth were stored in physiological saline solution (Sodium Chloride 0.9% saline solution) for three months to prevent dehydration. Physiological saline solution was chosen because, according to some studies, there is no significant difference between various storage solutions for extracted teeth in terms of mechanical properties [3,12].

The teeth were divided into three groups, each consisting of 8 teeth. Group 1 served as the control, included intact incisors and was designated as C. Group 2, labeled as CH, included incisors prepared with a chamfer bevel, while Group 3, named B45, contained incisors prepared with a 45° bevel.

For each tooth, two silicone keys were crafted, one to aid with the creation of the class IV cavity and one to aid at sealing the oral wall. These keys were made from putty condensation silicone (Zetaplus, Zhermack) and were cut at the incisal margin. The incisal angles of the teeth in the CH and B45 groups were cut to simulate a Black class IV cavity, indicating an incisal angle fracture. This cutting was performed using a 850/014 – Round End Taper diamond bur with a green turbine ring (Strauss Diamond). The class IV cavity was standardized with the help of the silicone key previously made at a height of 2 mm from the incisal margin and a width of approximately 4 mm. Subsequently, dental bevels were prepared (Figure 1). For the CH group, a chamfer bevel was created using a V801/014 – Round diamond bur with a green turbine ring (Strauss Diamond), while for the B45 group, the 45-degree bevel was formed using 850/014 – Round End Taper diamond bur with a green turbine ring (Strauss Diamond). All incisors were prepared in this manner to standardize the procedure.



A B

Figure 1. Dental bevels: A. 45-degree bevel; B. chamfer bevel.

The next step involved applying the adhesive system using the selective acid etching technique. The enamel margins were etched for 30 seconds with 37% orthophosphoric acid (ETCH-37, Bisco), after which the seventh-generation adhesive system from Ivoclar Vivadent, “Adhese Universal Vivapen,” was applied. Each tooth was light-cured for 20 seconds. Following the adhesive application, composite layering was performed. Initially, the oral wall was restored with enamel composite (Ceram.x® Duo, Dentsply Sirona, shades E1, E2, E3), aided by the previously fabricated silicone key. Subsequently, the proximal walls were rebuilt with enamel composite (Ceram.x® Duo, Dentsply Sirona, shades E1, E2, E3), followed by dentin body restoration using dentin composite (Ceram.x® Duo, Dentsply Sirona, shades D1, D2, D3). The final layer of composite, applied to the vestibular surface, consisted of enamel composite (Ceram.x® Duo, Dentsply Sirona, shades E1, E2, E3). Each composite layer was light-cured for 20 seconds.

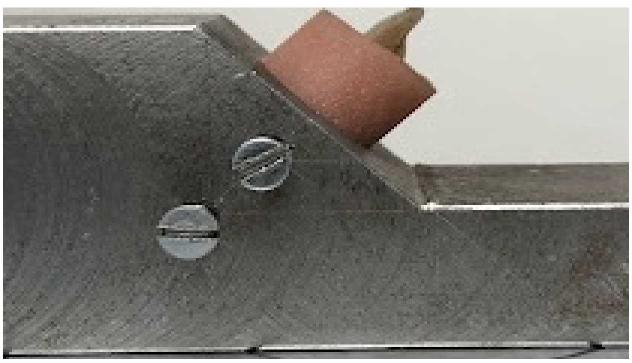


Figure 2. Mandibular incisor inserted into the acrylic material up to the level of the neck.

To induce fracture, the incisors were encased in self-polymerizing acrylic resin (“Duracryl Plus” by Spofa Dental) using a cylindrical former with a diameter of approximately 1.5 cm. The incisors were inserted into the acrylic material up to the level of the neck to closely mimic the situation in the oral cavity, ensuring that the test results were not influenced by the characteristics of the dental root (Figure 2).

Figure 3. Instron 3366 universal testing machine.

Once the teeth were embedded, they were placed in a metal holder at a 45° angle. Using the Instron 3366 universal testing machine (Figure 3) to assess the fracture resistance of the incisors, a compressive force was applied to them at the level of the incisal third at a constant crosshead speed of 2 mm per minute until either the tooth surface or the filling fractured or dislodged. The machine was set to determine the maximum compressive load that caused the fracture of the dental structure, measured in N.

Results

Following the fracture resistance testing of the mandibular incisor groups, the results from table I were obtained. Subsequently, a statistical analysis using the Student's T-test for independent variables was conducted for these values. This test was chosen because it aims to accept or reject a null hypothesis, which states that there are no statistically significant differences between the two compared groups. The statistical analysis was performed using the Social Science Statistics program (socscistatistics.com).

The mean maximum compressive loads for the control, chamfer, and 45° bevel groups, along with the standard deviation, were observed as 747.28 ± 431.77, 273.42 ± 148.76, 229.70 ± 106.96, expressed in N, and are presented in figure 4. The test results were rated significantly at a p-value below 0.05. Initially, the maximum compressive load values were compared between the control group and the chamfer bevel group. The p-value obtained was 0.005. Subsequently, the maximum compressive load values between the control group and the 45° bevel group were compared, yielding a p-value of 0.002. Thus, there is a statistically significant difference. These tests rejected the first null hypothesis, demonstrating that intact mandibular incisors are three times more resistant to fracture than mandibular incisors prepared and filled with dental bevels.

A new Student's t-test was conducted to compare the maximum compressive load values between the chamfer bevel group and the 45° bevel group. The resulting p-value was 0.25, indicating an insignificant difference statistically. This outcome confirmed the second null hypothesis.

Tabel I. The maximum compressive load for each dental group.

No	Control	Chamfer	45° bevel
1	701.87	256.23	423.78
2	160.42	181.71	148.46
3	558.97	458.8	180.39
4	683.55	199.42	308.02
5	1,000.26	461.42	196.36
6	1,001.42	112.07	315.09
7	1,535.57	109.59	128.22
8	336.19	408.11	137.27
P value C+CH)		0.005	
P value (C+B45)		0.002	
P value (CH+B45)		0.25	

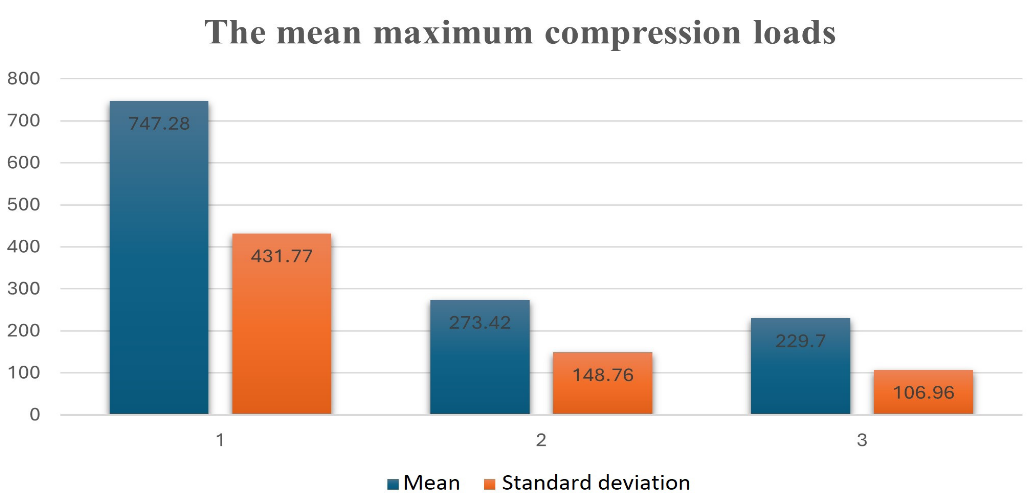


Figure 4. The mean value and standard deviation of the maximum compression load for each dental group.

Discussion

Anterior restorations rise numerous challenges in preparation and filling due to their visible placement in smiling, speaking, and indeed, in performing all functions of the dento-maxillary apparatus. The advent of composite resins and adhesive systems has revolutionized contemporary restorative dentistry, as they have altered the concepts of classical restorative dentistry and have made the emergence of new treatment options possible. These types of contemporary restorations are performed with minimal removal of dental structure, relatively short operating times, and significantly lower costs for patients compared to ceramic veneers and crowns.

However, for an anterior restoration to withstand the physiological and pathological conditions in the oral cavity for a longer period, it is necessary to focus not only on the type of material used in the restoration but also on the design and margins of the cavity, which can improve its longevity in the oral cavity. Numerous types of cavity margin preparations have been proposed, such as 90° margins, creating chamfer dental bevels, 45° bevels, long bevels, short bevels, etc., in order to achieve increased resistance and improved aesthetics of frontal fillings.

Epidemiological studies have shown that maxillary incisors are the most commonly involved in dental traumas [1,2]. Nevertheless, we shouldn't disregard the mandibular incisors, which hold the third position in terms of frequency. In this study, the analysis focused on mandibular incisors due to their significance in both aesthetics and functionality. Moreover, the limited number of studies investigating fracture resistance in mandibular incisors [11] underscores the need for deeper exploration in future research endeavors. The types of marginal preparations used in this study are based on a more aesthetic outcome [13], on the presence of a more reactive enamel for better retention due to the removal of aprismatic enamel [14]. Additionally, chamfer and 45° bevels are the most commonly used by clinicians [15].

However, some clinicians consider that beveling the cavity margins is a less conservative approach and may have a negative effect on the tooth-restoration interface. According to Soliman et al. [16], overextending the preparation with a bevel further thins the enamel margins and may negatively affect the restoration quality, stating that continuous and intact margins are essential for reducing marginal infiltration. Other clinicians and researchers believe that implementing a dental bevel automatically removes the aprismatic enamel layer and broken enamel prisms, thus improving adhesion [17-19]. Also, the expanded bonding area and removal of unsupported enamel through enamel bevelling could offer a notable advantage over composite restorations without bevelling. This technique also enhances the reactivity of enamel prisms to conditioning, thereby improving the bonding effectiveness of self-etch adhesives [20].

The 45° bevel is commonly used because it is a more conservative approach, especially for traumatized teeth, and results in a smooth color transition from the filling material to the tooth surface. However, in some fillings, thinning of the filling edges at the level of the bevel has occurred [15]. In comparison to the 45° bevel, the chamfer bevel provides a larger volume of filling material at the cavity margins, but it does not create as seamless a color transition between the filling material and the tooth surface.

In an in vitro study, the authors analyzed the marginal infiltration of Class II cavities with and without beveling the cavity margins of extracted temporary and permanent teeth. The results showed that fillings with beveled margins had improved marginal integrity and fracture resistance [16]. Marginal infiltration is one of the main causes of secondary caries, making it essential for cavity margins to be very well sealed. Another study, which examined the microleakage associated with composite restorations using two different bevel types, concluded that expanding the bonding surface area on the enamel can significantly reduce marginal infiltration. This outcome can be achieved by bevelling the margins of the preparation [21].

Various studies have demonstrated that preparing cavity margins with different types of bevels significantly improved fracture resistance compared to preparations without bevels [9,11,22,23]. Therefore, the use of dental bevels in daily practice is much more beneficial.

Looking at the first null hypothesis, we can argue that the present study invalidated it and thus that the control group of intact, unprepared teeth clearly exhibits higher mean values of maximum compressive loads compared to those of prepared teeth. This is due to the increased resistance of natural, intact teeth to complex forces compared to restored teeth. Similar results were also obtained by Eid H. [15], Bommanagoudar et al. [18], Coelho-de-Souza et al. [11], and Gandhi et al. [24].

Considering the second null hypothesis, statistical analysis couldn't invalidate it, which could mean that the mandibular incisors prepared with a 45° bevel present a higher fracture resistance than those prepared with a chamfer bevel. However, table I suggests that the mean values of the maximum compressive loads for the chamfer bevel group and the 45° bevel group indicate a higher value for the chamfer bevel group. Consequently, the chamfer bevel group exhibits greater resistance to fracture than the latter. The results of the t-test could be due to the smaller number of specimens tested. Similar statistically significant results were obtained by Bommanagoudar et al. [18], Tan et al. [23], and Gandhi et al. [24]. In contrast to these results, Coelho-de-Souza et al. [11] demonstrated that preparations with 45° bevels have higher fracture resistance compared to preparations with chamfer bevels. They also argue that 45° bevels offer several advantages:

removal of the superficial aprismatic enamel layer, which is richer in fluoride content, favoring acid etching; increased surface free energy, promoting surface wetting; enlargement of the exposed enamel surface; ensuring better marginal sealing. Peixoto et al. [25] showed that a chamfer-type marginal preparation could improve marginal closure compared to a 45° bevel preparation.

The limitations of this study included the prolonged immersion of specimens in distilled water, which, according to the study by Poojary et al. [19], leads to a decrease in the fracture resistance of extracted teeth. Including a larger number of dental specimens in the study could improve the statistical results regarding the significant difference in fracture resistance between anterior restorations made with chamfer bevels and those made with 45° bevels.

This study is among the few that analyze the fracture resistance of mandibular anterior teeth [11], which are frequently subjected to traumatic accidents and whose restoration is important for the proper functionality of the dento-maxillary system. In order to help clinicians to correctly restore mandibular incisors, further studies are needed to confirm that the best way to achieve this is by preparing the cavity margins with a chamfer bevel before restoring it with composite.

Conclusions

Within the limitations of this study, it can be concluded that intact teeth exhibit superior fracture resistance compared to teeth with coronal restorations following trauma or carious processes. Additionally, dental restorations made with a chamfer-type marginal preparation withstand greater forces, demonstrating improved fracture resistance compared to those made with a 45° bevel marginal preparation.

References

1. Andersson L. Epidemiology of traumatic dental injuries. J Endod. 2013;39(3 Suppl):S2-S5.
2. Lam R. Epidemiology and outcomes of traumatic dental injuries: a review of the literature. Aust Dent J. 2016;61 Suppl 1:4-20.
3. Brasil Maia G, Pereira RV, Poubel DLDN, Almeida JCF, Dias Ribeiro AP, Rezende LVML, et al. Reattachment of fractured teeth using a multimode adhesive: Effect of different rewetting solutions and immersion time. Dent Traumatol. 2020;36:51-57.
4. Garcia FCP, Poubel DLN, Almeida JCF, Toledo IP, Poi WR, Guerra ENS, et al. Tooth fragment reattachment techniques-A systematic review. Dent Traumatol. 2018;34:135-143.
5. de Sousa APBR, França K, de Lucas Rezende LVM, do Nascimento Poubel DL, Almeida JCF, de Toledo IP, et al. In vitro tooth reattachment techniques: A systematic review. Dent Traumatol. 2018;34:297-310.
6. Abdulkhayum A, Munjal S, Babaji P, Chaurasia VR, Munjal S, Lau H, et al. In-vitro Evaluation of Fracture Strength Recovery of Reattached Anterior Fractured Tooth Fragment Using Different Re-Attachment Techniques. J Clin Diagn Res. 2014;8:208-211.
7. Albers HF., DDS. Tooth-colored restoratives: principles and techniques. 9th. Edition; BC Decker Inc; 2002: p.122-134.
8. Xu H, Jiang Z, Xiao X, Fu J, Su Q. Influence of cavity design on the biomechanics of direct composite resin restorations in Class IV preparations. Eur J Oral Sci. 2012;120:161-167.
9. Coelho-de-Souza FH, Rocha Ada C, Rubini A, Klein-Júnior CA, Demarco FF. Influence of adhesive system and bevel preparation on fracture strength of teeth restored with composite resin. Braz Dent J. 2010;21:327-331.
10. Smith RL, Hood JA, Stokes AN. Influence of cavosurface configuration and composite resin type on impact fracture resistance of Class IV restorations. N Z Dent J. 1990;86:58-61.
11. Coelho-de-Souza FH, Camacho GB, Demarco FF, Powers JM. Influence of restorative technique, beveling, and aging on composite bonding to sectioned incisal edges. J Adhes Dent. 2008;10:113-117.
12. Kantoor P, Srivastava N, Rana V, Adlakha VK. Alterations in the mechanical properties of the extracted human teeth to be used as biological restorations on storing them in different storage media: an in vitro study. Dent Traumatol. 2015;31:308-313.
13. Albers HF. Principles and Techniques. Tooth-colored Restoratives Alto Books; BC Decker Inc , 2002; 9: 132-133.
14. Loguercio AD, Mengarda J, Amaral R, Kraul A, Reis A. Effect of fractured or sectioned fragments on the fracture strength of different reattachment techniques. Oper Dent, 2004;29:295-300.
15. Eid H. Retention of composite resin restorations in class IV preparations. J Clin Pediatr Dent. 2002;26:251-256.
16. Soliman S, Preidl R, Karl S, Hofmann N, Krastl G, Klaiber B. Influence of Cavity Margin Design and Restorative Material on Marginal Quality and Seal of Extended Class II Resin Composite Restorations In Vitro. J Adhes Dent. 2016;18:7-16.
17. Coelho-De-Souza FH, Camargo JC, Beskow T, Balestrin MD, Klein-Júnior CA, Demarco FF. A randomized double-blind clinical trial of posterior composite restorations with or without bevel: 1-year follow-up. J Appl Oral Sci. 2012;20:174-179.
18. Bommanagoudar J, Chandrashekhar S, Sharma S, Jain H. 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. Open Access Maced J Med Sci. 2019;7:4089-4093.
19. Poojary PK, Bhandary S, Srinivasan R, Nasreen F, Pramod J, Mahesh M. Influence of restorative technique, Bevelling and aging on composite bonding to sectioned incisal edges:

A comparative in vitro study. J Conserv Dent. 2013;16:28-31.

20. Schroeder M, Reis A, Luque-Martinez I, Loguercio AD, Masterson D, Maia LC. Effect of enamel bevel on retention of cervical composite resin restorations: A systematic review and meta-analysis. J Dent. 2015;43:777-788.
21. Rajagopal S, Sharma S. Comparative Evaluation of Marginal Leakage of Various Bevel Designs Using Direct Composite Restoration in Fractured Anterior Teeth: An In Vitro Study. Cureus. 2024;16:e56860.
22. Apel Z, Vafaeian B, Apel DB, Hussain A. Occlusal stresses in beveled versus non-beveled tooth preparation. Biomedical Engineering Advances. 2021;2:100010.
23. Tan DE, Tjan AH. Margin designs and fracture resistance of incisal resin composite restorations. Am J Dent. 1992;5:15-18.
24. Gandhi K, Nandlal B. Effect of enamel preparations on fracture resistance of composite resin buildup of fractures involving dentine in anterior bovine teeth: an in vitro study. J Indian Soc Pedod Prev Dent. 2006;24:69-75.
25. Peixoto RT, Poletto LT, Lanza MD, Buono VT. The influence of occlusal finish line configuration on microleakage of indirect composite inlays. J Adhes Dent 2002;4:145-150.