Retention of composite resin restorations in class IV preparations

Hani Eid

Clinicians often utilized composite resin restorations in combination with different types of preparation to restore class IV fractures on anterior incisors. A new preparation technique called (stair-step chamfer technique) is investigated in this study to detect bond strength to tooth structure. Eighty-eight bovine teeth were divided into 4 groups. Group I had twenty-three samples with a 45˚ bevel that extended 2 millimeters beyond the fracture line. Group II had twenty-three samples with a circumferential chamfer, which extended 2mm beyond the fracture line and half the enamel thickness in depth. Group III had twenty-three samples with a facial stair-step chamfer, which followed the anatomical contour and extended 2 mm beyond the fracture line with a lingual plain chamfer. Group IV had eighteen samples as controls, which were untreated teeth. The first three groups were prepared and restored with hybrid composite resin in conjunction with a single step bonding agent and as surface penetrating sealer, then tested for shear-bond strength on the Instron machine. The results were that there was no significant difference found between the treated teeth when tested for shear-bond strength. However, according to the site of the fracture, the stair-step chamfer technique gave significantly better results. It can be concluded that, the stir-step chamfer technique provides the clinician better environment to place a composite resin restoration resulting in good shear-bond strength and better esthetics.
J Clin Pediatr Dent 26(3): 251-256, 2002

INTRODUCTION

A new technique is being utilized to help solve the problems that have been associated with class IV composite restorations on anterior teeth. This method of preparation is termed the stair step chamfer technique. With this preparation we hope to improve both the esthetics and retention of this much used restoration technique.[3]

Historically, restoring fractured anterior teeth has evolved from the use of stainless steel crowns to the current procedures of bonded esthetic materials. However, despite current improvements, the technique of restorations and materials used, shared the problem of esthetics, longevity and durability. We will, perhaps, never replace adequately the esthetics and durability of the human tooth, but progress in current bonding materials brings the operator closer to this ideal.

Retention of resin restorations relied for the most part on the effectiveness and the durability of the bonding system that is being utilized. A recent article by Kugel summarized all generations of bonding agents and their evolution.[30] The first generation of resins was started when Buonocore introduced the use of a glycerophosphoric acid dimethacrylate- containing resin, which would bond to acid etched dentin. This bond was an interaction between this bifunctional resin molecule with the calcium ions of hydroxyapatite. However, it was found that the clinical results with this system were poor due to recurrent caries.[12]

In the late 1970s, the second-generation resin system was introduced, and the mechanism in bonding to dentin was through an ionic bond to calcium by chlorophosphate groups.

It was shown that those mechanical bonds were also weak especially in a moist environment.[2] It was discovered that a layer termed "smear-layer" prevented a proper mechanical bonding mechanism. Researchers began to over come this problem by etching dentin in combination with the third generation bonding system.[32] This generation of adhesion system uses a hydrophilic dentin-resin primer. This phosphate primer modifies the smear layer by softening it, however, the resins did not penetrate through the smear layer and the smear layer continued to be the weakness in the adhesion mechanism.[37]

The complete removal of the smear layer was achieved with fourth generation bonding systems. The enamel and dentin were etched with 40% phosphoric acid for 15 to 20 seconds. The dentin was kept moist, and not over etched to avoid collagen collapse.[24] The

* Dr. Hani Eid, third year postgraduate student, Pediatric Dentistry Department, Tufts University School of Dental Medicine, 1 Kneeland Street, Boston, MA 02111, USA.

disadvantage to this forth generation bonding system was the increase of multiple steps, which extended the complexity of clinical technique.

In order to simplify this multiple step procedure, researchers developed the one bottle system[22] and the self-etching primer bonding systems.[40] The self-etching primer system had some disadvantages that included the presence of a residual smear layer between adhesive materials and the dentin.[32] It was advised to use a separate etching step before bonding to produce a more reliable and durable bond to dentin. Recently, several bonding systems were developed and proposed as sixth generation of adhesive materials, but there is little data to date on effectiveness.

As research progresses, we are getting closer to the ideal bonding agent, but on the other hand researchers needed to provide the ideal material to bond to lost tooth structure. Previously the main concern of clinicians was function so they restored anterior teeth fractures with firm and solid restorations like cast crowns or stainless steel crowns, then pin retained restorations.[4,9,12,33,37]

However, the battle between functionally sound restorations and esthetics was a prime concern for both patients and clinicians. Clinicians started using acrylic restorations satisfying the esthetic demand in dentistry. Although those materials provided a short-term esthetic result, they lacked longevity and durability to biting forces or to mouth fluids.[10]

Research in composite dentistry devoted efforts toward finding the ideal restorative material. Composites are a combination of an organic binder and inorganic fillers incorporated into a system that would induce polymerization.[23] Usually filler particles are coated with a coupling agent to bond to the resin matrix.[35] Changing the particle size and filler shape has improved the wear resistance of the early composite resins.[36]

Polymerization shrinkage is a major disadvantage of the current composites. This shrinkage is markedly reduced when incorporating filler particles, therefore the higher the filler loading the less shrinkage should take place. Composite-based resins are classified according to the particle size. Commonly, composite based resins are referred to as hybrids or microfills. The new hybrid type of composite that is being utilized today is considered to provide the clinician with better handling properties, acceptable aesthetics, higher surface smoothness, less working and setting time, higher marginal adaptation and better adhesion to tooth structures.[1,26,27,31]

Preparation techniques have also varied overtime to adapt to the different types of materials, which were in use. Various enamel preparation techniques have been recommended such as butt joint margins, feathered edge margins,[9] 45 degrees bevels,[10,13] threaded pin and retentive slot preparations,[21,25] chamfer preparation,[10,14,15,41] short bevel,[42,43] and long bevels have been utilized to help improve esthetics.[19]

In 1983 Black *et al*., described the effect of cavity design on retention of class IV composite restorations and recommended the 45 degrees bevel of 2mm extending to the entire enamel thickness. This design had better retention than the feathered edge and chamfer preparations.[10] Some investigators found that beveling the enamel surface would increase composite bonding strength to acid-etched enamel and decreased the chance of restoration fractures.[6,7] Longer enamel bevels were utilized in class IV restorations for composite resins because it allowed gradual transition of color from the tooth shade to the matching composite shade, giving the restoration a good esthetic result. However, the strength of the this preparation design and the accompanying restoration was not properly investigated by researchers.[6,17-19]

Circumferential chamfer preparation allows a finite finish line for the composite restoration in addition to providing marginal bulk, which essentially eliminates white line margin to an extent.[14] Later, other investigators compared chamfer and bevel preparations for retention and they found that chamfered preparations provided greater restoration fracture resistance and higher retention to tooth structures.[15,16]

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. This preparation showed good esthetic results because the chamfer margins and the vertical contours between the lobes overlap making difficult to locate the chamfer margins.[3]

Although many investigators used various tooth preparations and restorative materials, we continue to have no distinct guidelines for restoring class IV fractures with resin composites. The purpose of this study is to compare the shear strength values between the stair step chamfer preparation, the bevel preparation and the plain chamfer preparation techniques in class IV restorations on permanent incisors that are restored with hybrid resin composites by using the Instron machine. It is hoped that from this study we will be able to give the clinician more information on restoring the anterior incisor fractures.

MATERIALS AND METHODS

The samples for this study consist of 88 bovine incisor teeth that were freshly harvested from the slaughterhouse. The teeth were cleaned of soft tissues and washed thoroughly with tap water, then were frozen to maintain ``freshness`` during storage.[38] Each tooth was mounted in a 0.5-in diameter cylinder of acrylic resin and numbered. The teeth were then polished with

pumice using a soft rubber cup in a slow speed hand piece. The teeth were equally and randomly divided into 4 groups as shown in Table I. A 3mm standardized mesial fracture was created incisally, using a No. 48 XF diamond bur, in a high-speed hand piece, with water coolant. All preparations were made using fine diamond bur (No. 48 XF), using a high-speed hand piece with water coolant. There were 4 different groups that were tested.

Group 1: The bevel preparation: it had a 45˚ inclination bevel on the cavosurface margins of the tooth around the entire enamel periphery and extends 2mm cervically.

Group 2: The chamfer preparation: it had chamfer shoulder preparation around the entire enamel periphery and extended cervically approximately 2 mm beyond the edge of the fractured enamel and involved half of the enamel thickness in depth.

Group 3: The stair step chamfer preparation: it had 1mm depth, and 2 mm width chamfer into the enamel around the cavosurface margins with doing stair steps that follow the anatomical vertical and horizontal lines of the front teeth.

Group 4: The control group: these were untreated teeth.

Table I.

Group no.	Type of preparation	No. Teeth
Group I	Bevel Technique	23
Group II	Chamfer technique	23
Group III	Stair-step chamfer technique	23
Group IV	Control (non treated)	18

The restorative materials were applied according to the manufacturer's directions. The enamel margins were acid-etched with 37% phosphoric acid gel for 20 seconds and the dentin for 10 seconds, and then thoroughly rinsed with water. To keep the dentine surface moist, a damp cotton pellet was placed on the dentin surface and removed just before bonding. A bonding agent (Excite, Vivadent) was placed and polymerized for 20 seconds.

Preparation of groups 1, 2 and 3 were restored with Tetric Ceram. By using the incremental layer technique with pressure using a plastic instrument, and each layer was cured for 40 seconds. Finishing was accomplished with a diamond bur and polishing points. A surface penetrating sealant Fortify (Bisco Corp.) was applied to the surface of the restoration and cured for 40 seconds. This sealant was used as a thin viscosity unfilled resin for penetration and sealing of any micro fractures generated during placement and finishing procedures. The completed specimens were placed in water for a week in accordance to the standards establish by Koike.[29]

An Instron testing machine was used to test the strength of the preparations. The block containing the restored tooth was secured to a mounting jig to provide a 90˚ angle between the incisal edge of the restoration and the Instron testing crosshead. This direction of mechanical force was performed so as to simulate a blow to tooth from the facial side. The Instron crosshead was then aligned to contact the mesial buccal incisal edge of the restoration during testing, at a speed of 0.5mm/min, until the specimen fractured. The fractured specimens were evaluated visually. The results were then recorded from the instron machine.

STATISTICAL ANALYSIS

Sample size was determined by using the results of a pilot study of four test groups. The resulting means led to a sample size of 15 to 20 specimens each to detect preparation technique differences. The reading of the force load (Newton) from the Instron machine was divided on the surface area (square millimeter) of the sample to result in the shear strength (Mega- Pascal) of the sample. The means of the fracture shear strength for the four groups were compared for statistical significance by one-way Analysis of variance (ANOVA).

It was also noticed when evaluating the fractured samples that some of the samples were fractured at the interface between the restoring material and the cavosurface of the prepared tooth, while others had the fracture within the restoring material. This led to another comparison between the groups according to the site of the fracture, and a Chi- Square analysis test was performed to compare groups I, II, and III.

RESULTS

The results of the first ANOVA test showed a significant difference of the shear strengths in mega pascal between the control group (Untreated samples) and the three different preparation techniques P level <0.001, and no significant difference among the different types of preparation P level > 0.05. These data are represented in Table II, Figures 1, and 2.

Table II. ANOVA test for shear strength

Group	N	Subset for alpha = .05	
		1	2
Chamfer	23	14.9343	
Bevel	23	15.1530	
Stair-step Chamfer	23	20.0357	
Control	19		47.0905

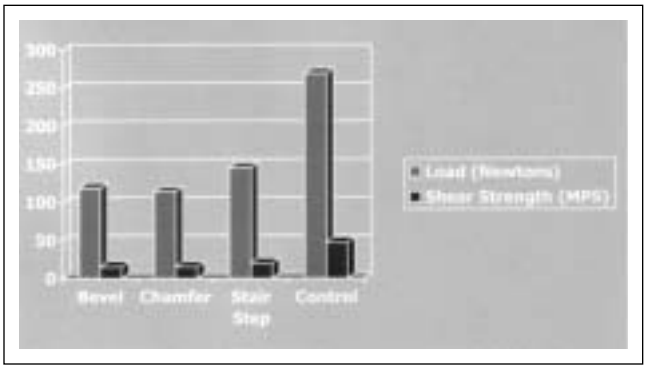

Figure 1. Means of load and shear strength between all groups.

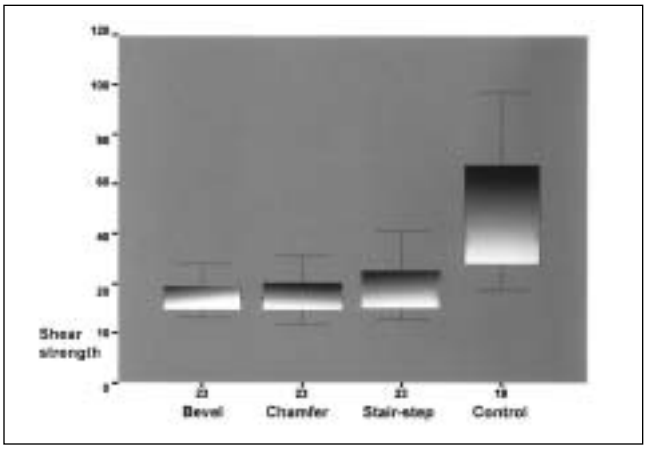

Figure 2. The calculated mean shear strengths and standard deviation (SD) are listed in (table III).

Table III.

Group	Mean	N	Std. Deviation	Std. Error of Mean
Bevel	15.1530	23	6.4795	1.3511
Chamfer	14.9343	23	7.4111	1.5453
Stair-step chamfer.	20.0357	23	14.1163	2.9434
Control	47.0905	19	24.8701	5.7056
Total	23.2676	88	19.1138	2.0375

Table IV.

	Site of Fracture	
Prep Type	Within Restoration	Interface
Stair Step	20	3
Chamfer	3	20
Bevel	3	20

DISCUSSION

Currently most clinicians prefer to use either the bevel or the chamfer techniques. The bevel is widely used because conservative approach especially to traumatized teeth and to the gradient color change from tooth matter to the restoring material, on the other hand the fragile margins of the restoring material frequently deteriorated over the years. While the chamfer provided more bulk to the restoring material on the margins. It failed to blend with tooth color on the fracture line where the interface between the enamel and the composite resin.

After thoroughly examining the samples of all the prepared teeth, it was noticed that the fracture was more within the restoring material rather than at the interface between the material and the tooth structure, in the stair-step technique. This indicates that it was not the adhesion between the composite resin and tooth structure that failed, rather the cohesive strengths within the restoring material itself. This could be attributed to the fact that there was an increased surface area of enamel available for bonding in the stair-step chamfer preparation technique than the other types of preparation. This fact puts the stair step chamfer technique possibly in a superior position in both strength and esthetics to the other techniques, however, more testing is needed to prove the potential improvement.

Although it was found previously that the multiple layer insertion technique gave better retentive results when used with the bevel and chamfer preparation techniques, it is recommended to investigate this factor in conjunction with the stair-step in future studies.

The use of hybrid composite resin proved previously to be more resistant to shear strength than the microfilled resins. Microfilled composite resins give the operator more control to contour and polish the restoration resulting in a more esthetic appearance. Testing those two types of restoring material with the stair-step chamfer technique would be an additive expansion to complete this investigation. It is difficult to perform an *in vivo* comparison study between those different types of preparations due to the individual variances of *in vivo* studies.

Human anterior incisors could not be obtained in sufficient numbers; hence, bovine incisors of a uniform size and shape were used. In previous studies it was found that bovine teeth were suitable for evaluating the restorations made by acid etching technique. However, the bond strength of composite resins to bovine enamel is slightly lower than to human teeth.[4,5,31]

The surface area of the fractured restorations was calculated in approximation according to the shape of the area. The results would have been more accurate if the surface area was measured precisely instead of approximation to get more accurate readings.

CONCLUSION

The following conclusions can be drawn from this investigation:

1. There is no significant difference in shear strength between the bevel, plain chamfer, and stir-step chamfer techniques.

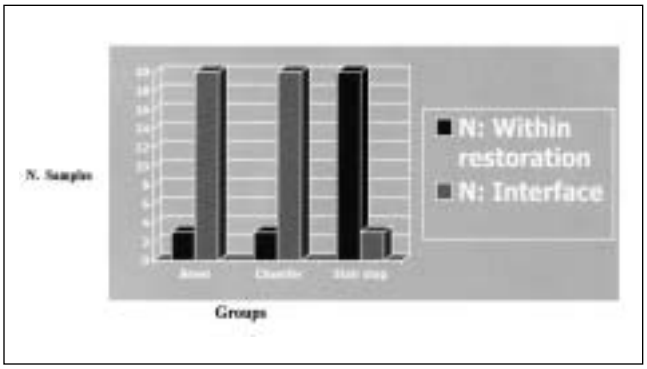

Figure 3. Fracture site between groups I, II, III.

2. There is a significant difference in shear strength between the control group (untreated teeth) and the previous groups, as it was anticipated.
3. There is a significant difference between the stair-step chamfer technique and the bevel and plain chamfer techniques in the site of fracture where composite resin had a better bond to tooth surface when utilizing the stair-step chamfer technique.
4. The stair-step chamfer technique has better esthetic outcome with bonded composite resin restoration, due to its design that follows the anatomical contour of the human anterior incisors.

Based upon the previous conclusions the author recommends to the clinicians the utilization of the stair-step chamfer technique to restore class IV fractures in anterior incisors.

REFERENCES

1. Abdullah, AL, Davidson, CL. Shear strength and microleckage of new dentin bonding systems. Am J Dent 6: 295-298, 1993.
2. ADA council on dental materials. Instruments and equipment. Dentin bonding systems: an update. JADA 114: 91-95, 1987.
3. Albers AF. Class IV composite restorations. Tooth-colored restoratives. Alto Books, edition #8 (8b1-8b6), 1996.
4. Attin T et al. Fracture toughness of pin retained class IV restorations. Oper Dent 19: 110-115, 1994.
5. Badami A. et al. An in vitro investigation the shear bond strength of two dentin bonding agents used in the reattachment of incisal edge fragments. Endod Dent Tramatol 11: 129-135, 1995.
6. Bagheri J, Denehy GE. Effect of enamel bevel and restoration length on class IV acid-etch retained composite restoration. JADA 107: 951-953, 1983.
7. Bagheri J. Denehy GE. Effects of restoration thickness at the cavosurface bevel on the class IV acid etch retained composite resin restoration. JADA 107: 175-177, 1985.
8. Barkmeier, W W, Cooley RL. Shear bond strength of tenure solution dentin bonding system. Am J Dent 2: 263-265, 1989.
9. Bichacho, N. Direct composite resin restoration of the anterior single tooth: Clinical implications and practical applications. Compendium l7: 796-802, 1996.
10. Black J. Retief D. Lemons J. Effect of cavity design on retention of class IV composite resin restorations. JADA 107: 42-46. 1983.
11. Buonocore M, et al. A report on resin composition capable of bonding to human dentin surface. J Dent Res 35: 846-851, 1956.
12. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res 34: 849-853, 1955.
13. Caeg C, et al. Effectiveness of a method used in bonding resin to metal. J Prosthetic Dent 64: 37-41, 1990.
14. Davidson DF, Jordan RE. Esthetic conservative incisal restoration of anterior teeth. Clinical J 60: 301-4, 1994.
15. Davis MJ, et al. Marginal integrity of adhesive fractured restorations: Chamfer versus bevel. Quintessence Internat 14: 1135-1139, 1983.
16. Donly K, Browing G. Class IV preparation design for microfilled and macrofilled composite resin. Pediatr Dent 2: 14-21, 1992.
17. Fahl N. Predictable aesthetic reconstruction of fractured anterior teeth with composite resins. Practical Periodontics and Aesthetic Dentistry 8: 17-18, 1996.
18. Fahl N, Swift EJ. The invisible class IV restoration. J Esthetic Dent 1: 11-13, 1989.
19. Fahl N Jr. Optimizing the aesthetics of class IV restorations with composite resins. Canadian Dent Assoc J 63: 108-111,114-115, 1997.
20. Fanning D, Wakefield C. Effect of a filled adhesive on bonding strength in three dentinal bonding systems. General Dent 43: 256-261, 1995.
21. Felton SA. Pulpal response to threaded pin and retentive slot techniques. J Prosth Dent 66: 597-602, 1991.
22. Ferrari M, et al. Bonding mechanism of three "one-bottle" systems to conditioned and unconditioned enamel and dentin. Am J Dent 10: 224-230, 1997.
23. Fortin D, Vargas M. The spectrum of composites: New techniques and materials. JADA 124: 265-305, 2000
24. Fusayama T, et al. Non-pressure adhesion of a new adhesive restorative resin. J Dent Res 58: 1364-1372, 1979.
25. Garman TA. Clinical comparison of dentinal slot retention with pin retention. J A D A 107: 762-763, 1983.
26. Gray L. A review of composites. J Acad Gen Dent 19: 12-16, 1971.
27. Hombrook DS. Repair of class IV fractures utilizing resin and porcelain. Practical Periodontics and Aesthetic Dentistry 5: 55-62, 1993.
28. Jordan RE, et al. Resin-enamel bonding. Esthetic composite bonding techniques and materials, 26-91, 1986.
29. Koike T. Hasegawa T. Manabe A. Itoh K. Wakumoto S. Effect of water sorption and thermal stress on cavity adaptation of dental composites. Dent Mat 6: 178-80, 1990.
30. Kugel, G. Ferrari, M. The science of bonding: from first to sixth generation. JADA 124: 205-255, 2000.
31. Loid CH, Scrimgeour. Dental Materials. J Dent 25: 173-208, 1997.
32. Nakabayashi N, Pashley DH. Hybridization of dental hard tissue. Tokyo Quintessence. 1998.
33. Nelson S, Till M. Comparison of materials and methods used in acid etch restorative procedures. JADA 89: 1123-1127, 1974.
34. Osborne JW, Lambert RL. Restoration of fractured central incisor using original tooth fragment. Gen Dent 33: 516-517, 1985.
35. Philips RW. Science of dental materials 8th edition. Philadelphia: Saunders, 224, 1982.
36. Sturdevant, CM. The art and science of operative dentistry. 3rd Edition, St. Louis, Mosby, p. 265, 1995.
37. Tao L, Pashley DH, Boyed L. The effect of different types of smear layers on dentin and enamel bond strength. Dent Mat 4: 208-216, 1988.
38. Titley K, et.al. The effect of various storage methods and media on shear-bond strengths of dental composite resin to bovine dentine. Arch Oral Biology 43: 35-311, 1998.
39. Vincent P, Vissichelli. Restoration of a fractured maxillary central incisor by using the original tooth fragment. Gen Dent 5: 238-240, 1996.

40. Watanabe I, Nakabayashi N. Bonding durability of photocured phenyl-P in TEGDMA to smear layer-retained bovine dentin. Quintessence Int 24: 335-242, 1993.
41. Welk DA, Laswell HR. Rational for designing cavity preparations in light of current knowledge and technology. Dent Clin North Am 20: 231, 1976.
42. Yates, Hembree. Fractures resistance of class IV composite restoration. Arkansas Dent J 48: 10-14, 1977.
43. Zalkind M, Heling I. Composite resins layering: an esthetic technique for restoring fractured anterior teeth. J Prosth Dent 68: 204-205, 1992