Effect of Surface Conditioning and Taper Angle on the Retention of IPS e.max Press Crowns

Manal M. A. Madina, DDS, PhD,[1] Mutlu Özcan, Dr.Med.Dent., PhD,[2] & Manal F. Badawi, DDS, PhD[3]

[1] Department of Conservative Dentistry, Mansoura University, Faculty of Dentistry, Mansoura, Egypt
[2] University of Zürich, Dental Materials Unit, Center for Dental and Oral Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Zürich, Switzerland
[3] Department of Dental Biomaterials, Mansoura University, Faculty of Dentistry, Mansoura, Egypt

Keywords
Adhesion; all-ceramic; cementation; retention; taper angle.

Correspondence
Mutlu Özcan, University of Zürich, Dental Materials Unit, Center for Dental and Oral Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Plattenstrasse 11, CH-8032, Zürich, Switzerland. E-mail: mutluozcan@hotmail.com

Accepted: March 3, 2009

doi: 10.1111/j.1532-849X.2009.00547.x

Abstract

Purpose: The objective of this study was to evaluate the retentive strength of single-unit crowns with 10° and 26° taper angles cemented using two surface conditioning methods.

Materials and Methods: Thirty-two freshly extracted sound human molars were divided into two groups (n = 16) and prepared in a standardized manner with 10° and 26° taper angles. All-ceramic (IPS e.max Press) single crowns were fabricated for the prepared teeth. The crowns were then subdivided into two groups (n = 8), according to type of surface conditioning for the intaglio surfaces. Half the groups were HF acid etched and silanized, and the other half were conditioned with tribochemical silica coating and silanization. The crowns were cemented using adhesive cement (Panavia F 2.0). Retentive strength was measured in a universal testing machine.

Results: No significant difference was found between the mean retention forces for both 10° and 26° taper angles when the crowns were conditioned either with silica coating (613 ± 190 N and 525 ± 90 N, respectively), or with hydrofluoric (HF) acid etching and silanization (550 ± 110 N and 490 ± 130 N for 10° and 26°, respectively) ($p = 0.32$).

Conclusion: Neither the surface conditioning type, nor the taper angle affected the retentive strength of IPS e.max Press single-unit crowns when cemented adhesively. Since silica coating and silanization did not show significant differences from HF acid gel and silanization, the former can be preferred for conditioning intaglio surfaces of glass ceramic crowns to avoid the use of the hazardous compound HF acid gel chairside.

All-ceramics became the common material of choice for single-unit crowns or multiple-unit fixed partial dentures (FPD) due to their esthetic appeal as opposed to their metal-ceramic counterparts.[1] Strong and reliable adhesion could be provided by resin-based luting systems.[2,3] Recently, heat-pressed all-ceramic materials that contain lithium disilicate as a major crystalline phase have become available. One such system is IPS e.max Press, heat-pressed between 890 and 1120°C, with which single crowns or multiple-unit FPDs can be fabricated for both the anterior and posterior region of the mouth. The lithium disilicate-containing ceramics have sufficient flexural strength (350 to 400 MPa) and fracture toughness (3.2 $MPa.m^{1/2}$), extending their range of clinical applications.[4] With heat-pressed ceramics, large pores caused by non-uniform mixing, extensive grain growth, or secondary crystallization that occurs often during sintering can be avoided.[5] Longevity of all-ceramic FPDs mainly rely on adequate adhesion of the resin-based luting cements both to the tooth tissues and the ceramic surface.[4]

Adhesion of luting cements increases the fracture resistance of the tooth and the restoration itself. It also increases the retention of the restoration and minimizes microleakage that may play a role in the biological success of the restoration.[2,6,7] Predictable adhesion between resin luting cements and glassy matrix ceramics is usually created by several mechanisms. Micromechanical retention provided by hydrofluoric (HF) acid etching followed by the application of a silane coupling agent is one of the most commonly accepted conditioning methods.[8-11] Bonding of the resin occurs by an additional polymerization reaction between methacrylate groups of the resin matrix and the silane molecule.[12] Moreover, a silane coupling agent enhances

the ceramic-resin adhesion by promoting the wettability of the ceramic surface, thus making the penetration of the resin into the microscopic porosities of the conditioned ceramic surface more ideal.[13-18] Since HF acid gel is a poisonous and caustic compound, it presents a potential health hazard due to its toxicity and volatility.[11] As an alternative to HF acid gel, advances in adhesive dentistry have resulted in the introduction of modern surface conditioning methods. Silica coating and silanization is one of these methods. In this technique, the surfaces of the restorative materials are airborne particle abraded with aluminum trioxide particles modified with silica. The blasting pressure results in the embedding of these particles on the ceramic surface, rendering the silica-modified surface chemically more reactive to the resin through silane coupling agents.[19-21]

Retention of the single-unit crowns is also dominated by the taper angle-–the angle of convergence between the opposing axial walls. The retention of FPDs has been shown to depend on the taper angle: the smaller the taper angle, the higher the retention.[22] The maximum retention is obtained between 6 and 12°.[22] In practice, ideal axial wall convergence may not be routinely obtained. Studies have reported mean taper angles ranging from 3 to 26°.[23-28] Among several factors, lack of retention was shown to be a common reason for failure of FPDs.[29-31]

It is, however, not known whether retention obtained with surface conditioning could be impaired when single-unit crowns have an increased taper angle. To the authors' knowledge, no study has been conducted comparing the surface conditioning and the retentive properties of all-ceramic single-unit crowns in conjunction with the taper angle. The objective of this study, therefore, was to evaluate the retentive strength of single-unit crowns with 10° or 26° taper angles when crowns were cemented using two surface conditioning methods. The research hypothesis was that increased taper angle would result in decreased retention, regardless of the surface conditioning method.

Materials and methods

Thirty-two recently extracted sound human molars were used for this study. Upon collection, adhering soft tissues and blood were removed under running water. The teeth were stored in a 1% chloramine-B hydrate disinfectant solution for a week[32] and then stored in distilled water until use. Undercuts were prepared in the roots of the teeth. The teeth were then mounted in metal rings with their coronal parts upwards using an autopolymerizing acrylic resin (Meliodent, Bayer Dent, Newburg, Germany).

Teeth were randomly divided into two groups (n = 16) according to the degree of taper angle. While axial walls of half of the teeth were prepared with 10°, the other half was prepared with 26° under controlled conditions. The occlusal surface of each specimen was reduced to a flat plane perpendicular to the long axis. All the resulting preparations had the same coronal height (3 mm). The preparations were performed on a lathe (AB Machine Tools LTD. SGia M/C No. 17531, Edmonton, Canada) using a cross-slide carbide insert tool at a speed of 400 rpm under coolant water.[33] Burs of 125 μm and 30 μm torpedo-shaped, and 125 μm and 30 μm conical-shaped diamonds (Komet, Lemgo, Germany) were used.[33] New burs were used after preparation of every four teeth. Preparations were made by one operator throughout the experiment. After preparation, the teeth were stored in distilled water until cementation process.

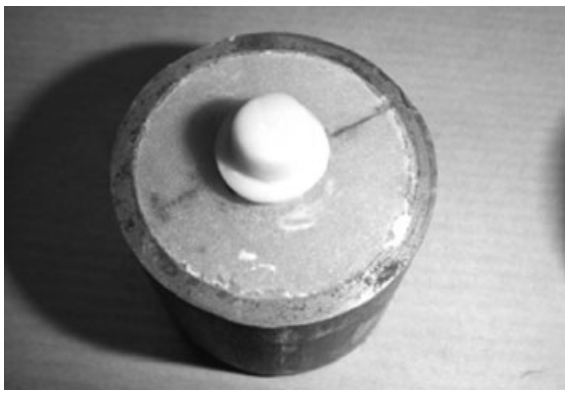

Figure 1 IPS e.max Press crown with overhanging margins on the tooth embedded in the metal ring in PMMA.

The impression of each prepared tooth was made with poly(vinyl siloxane) (Coltene, Whaledent, Altstätten, Switzerland) and poured with type IV improved plaster (GC, Fuji Rock, Leuven, Belgium) to obtain stone dies. Each stone die was carefully removed from the impression and examined for presence of air bubbles or other defects. Then die spacer was applied to the stone dies, 1 mm above the cervical end of the preparation to ensure good marginal fit.

Single-unit all-ceramic IPS e.max Press (Ivoclar Vivadent, Schaan, Liechtenstein) crowns were fabricated using the lost-wax technique and by pressure injection of ceramic ingots in the EP500 furnace (Ivoclar Vivadent) following the manufacturer's recommendations. The crowns were constructed with overhanging margins in the completed crown restorations from which the crowns were pulled to accomplish the retention test (Fig 1).[33] The crowns had flat occlusal surfaces, 2 mm at the occlusal, 2 mm at the axial, and 1.5 mm at the margins. The produced ceramic crowns were randomly divided into two subgroups for two surface conditioning methods.

The intaglio surfaces of one group of crowns were conditioned with 5% HF acid gel (IPS Empress HF gel, Ivoclar Vivadent) for 20 seconds, rinsed for 30 seconds, and dried with compressed oil-free air for 30 seconds.[3] This was followed by application of the silane coupling agent (3M ESPE, Seefeld, Germany) that was allowed to evaporate for 3 minutes and air-dried for 30 seconds.[3] The intaglio surfaces of the other group of crowns were treated with air abrasion with aluminium-dioxide-modified particles at a pressure of 3 bar from a distance of 10 mm for 13 seconds,[21] followed by application of the silane coupling agent that was allowed to evaporate for 3 minutes and air-dried for 30 seconds.

All teeth were cemented according to the protocol of Panavia F 2.0 (Kuraray Medical Inc., Osaka, Japan) following the manufacturer's recommendations. A thin film of luting agent was applied to the intaglio surface of the crowns with a plastic instrument. The crowns were seated on their corresponding tooth

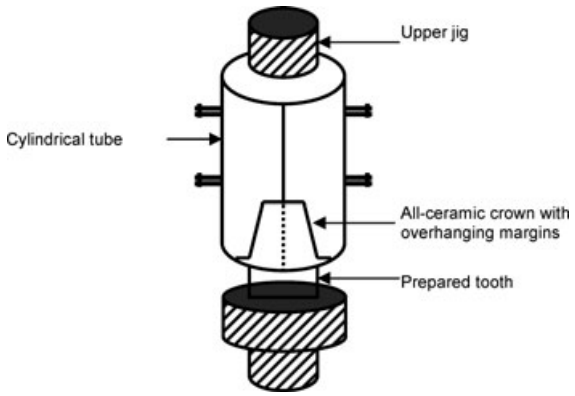

Figure 2 Apparatus for retentive strength measurement.

under a constant load of 5 kg for 10 minutes. Excess was removed using microbrushes.

A longitudinally split cylindrical steel tube (10 cm long) was reassembled using two steel screws.[33] The lower end of the tube was designed to accommodate the overhanging margins of the cemented crowns. The upper end of the tube was designed to be attached to the moving jig of the universal testing machine (Lloyd Instruments LTD, West Fareham, UK) (Fig 2). Each cemented specimen was fixed to the table of the testing machine, and debonding force was determined. Cemented crowns were pulled off along the path of insertion with a crosshead speed of 10 mm/min, and the maximum force to debond each crown was considered as retentive strength. Maximum pull-out force of the jig of the universal testing machine was set to 2000 N.

Statistical analysis was performed using SAS System for Windows, version 8.02/2001 (Cary, NC). The means of each group were analyzed using two-way ANOVA. Tukey's test was used with the retentive force being the dependent variable and the taper angles and surface conditioning methods as independent variable. p values less than 0.05 were considered to be statistically significant in all tests.

Results

No significant difference was found between the mean retention forces for both 10° and 26° taper angle when the crowns were conditioned either with silica coating (613 ± 190 N and 525 ± 90 N, respectively) or HF acid etched and silanized (550 ± 110 N and 490 ± 130 N for 10° and 26°, respectively) ($f = 3.39$; $p = 0.32$) (Table 1). Multiple statistical comparisons between the experimental groups according to Tukey's test are presented in Table 2.

Table 1 Mean retentive strength (N) (± standard deviations) of IPS e.max Press crowns. Same superscript letters in a row indicate no significant differences ($\alpha = 0.05$)

	10° taper angle	26° taper angle	p values
Silica coating and silanization	613 ± 190[a]	525 ± 90[a]	$p > 0.05$
HF acid etching and silanization	550 ± 110[a]	490 ± 130[a]	$p > 0.05$

Table 2 Multiple comparisons between the experimental groups in terms of statistical differences

	Silica-coating and silanization/26° taper angle	HF acid etching and silanization/26° taper angle
Silica-coating and silanization/10° taper angle	0.370	0.35
HF acid etching and silanization/10° taper angle	0.778	0.991

Discussion

Since retention has always been a concern in prosthetic dentistry, this study was undertaken to evaluate the retentive strength of all-ceramic single crowns as a function of taper angle and surface conditioning. The most difficult technical aspect of this study was connecting the all-ceramic crowns to the upper jig of the universal testing machine without damaging the crowns themselves during the retention test. Based on several pilot tests, a special cylindrical metal tube was designed to accommodate the overhanging margins of the cemented crowns that did not cause any breakage of the crowns during force application. Two taper angles were studied (10°, 26°) where the latter was reported by Nordland et al as the extreme occlusal tapering that could affect the retention of crowns.[27] On the other hand, a 10° taper angle was chosen because Weed and Baez[25] and Dodge et al[26] found non-significant retention values between the preparations made with 3° to 16° taper angles. Although there was a trend for higher retention values with a 10° taper angle with both surface-conditioning methods studied, no significant effect of taper angle was found on the retention. Therefore, the hypothesis was rejected. The reason for this could be attributed to the luting cement (Panavia F2.0) used, as it adheres to both the tooth structure and the crown substrate mechanically and chemically. Also, the use of silane-coupling agents as adhesive promoters, capable of forming chemical bonds to organic and inorganic surfaces, contributes further to the adhesion of the cement to the ceramic surfaces, thereby the retention. Even though higher mean retention values were recorded with tribochemical silica coating and silanization, the results were not significant as compared to that of HF acid-treated groups. Tribochemical silica coating and silanization increases the silica content on the ceramic surface and enhances the adhesion between the ceramic surface and the luting cement. On the other hand, the obtained microporosity increases the surface area and makes micromechanical interlocking of the resin possible. In spite of that, conditioning method did not affect the retention results significantly. A previous clinical study with zirconia ceramic, where adhesion of the resin cement is much inferior compared to glassy matrix ceramics, has also reported that silica coating was not necessary for the cementation of zirconia;[33] however, glass matrix ceramics cannot be compared with oxide-based ceramics such as zirconia in terms of cementation protocols. Zirconia is an inherently stronger material than glass ceramics, and therefore

the latter needs to be adhesively cemented to improve their tensile strength.

Although no clinical report exists in the dental literature regarding the hazardous consequences of HF acid gel, caution should be exercised when handling this material. Based on the insignificant differences between the two surface conditioning methods, and considering the possible hazardous effects and the non-significant differences between HF acid etching and silica coating, clinicians may consider the use of the latter for safer application; however, after both conditioning methods, silane application is compulsory,[12,21] and silica coating requires additional armamentarium in the dental practice, adding to the cost of this conditioning system.

In this study, the coronal length of the preparations was kept at 3 mm, similar to a previous study.[33] This coronal length could be considered as the minimum where mechanical retention may be impaired. Longer preparations or smaller taper angles, where available, may contribute to better retention. Nevertheless, both factors could be compensated for with the adhesive luting cement tested. Because no aging conditions were implemented, the results represent early clinical failures. Further in vitro studies are needed using a similar methodology but with long-term storage in an aqueous medium to investigate whether the retention of such crowns would be affected. Furthermore, clinical studies should incorporate factors associated with retention to find out the most dominant factor playing a role in retention of such restorations.

Conclusion

From this study, the following could be concluded:

1. neither the surface conditioning type nor the taper angle affected the retentive strength of IPS e.max Press single-unit crowns when cemented adhesively;
2. since silica coating and silanization did not show significant differences from HF acid gel and silanization, the former can be preferred for conditioning intaglio surfaces of glass ceramic crowns to avoid the use of the hazardous compound HF acid gel.

References

1. Rosenblum MA, Schulman A: a review of all ceramic restoration. J Am Dent Assoc 1997;128:297-307
2. Blatz MB, Sadan A, Kern M: Resin-ceramic bonding: a review of literature. J Prosthet Dent 2003;89:268-274
3. Filho MA, Vieira LC, Araujo E, et al: Effect of different ceramic surface treatments on resin microtensile bond strength. J Prosthet Dent 2004;13:28-35
4. Van Dijken JW: All-ceramic restorations: classification and clinical evaluation. Comp Cont Educ Dent 1990;20:1115-1136
5. Denry LI: Recent advances in ceramics for dentistry. Crit Rev Oral Biol Med 1996;2:134-143
6. Sorensen JA, Kang SK, Avera SP: Porcelain-composite interface microleakage with various porcelain surface treatments. Dent Mater 1991;7:118-123
7. Sibylle H, Jurgen S: The compatible all-ceramic system. J Dent Technol 2006;70:324-330
8. Horn HR: Porcelain laminate veneers bonded to etched enamel. Dent Clin North Am 1983;27:671-684
9. StangeI L, Nathanson D, Hsu CS: shear strength of the composite bond to etched porcelain. J Dent Res 1987;66:1460-1465
10. Aida M, Hayakawa T, Mizukawa K: Adhesion of composite to porcelain with various surface conditions. J Prosthet Dent 1995;73:464-470
11. Bertolini JC: Hydrofluoric acid: a review of toxicity. J Emerg Med 1992;10:163-168
12. Soderholm KJ, Shang SW: Molecular orientation of silane at the surface of colloidal silica. J Dent Res 1993;72:1050-1054
13. Baily LF, Bennett RJ: Dicor surface treatments for enhanced bonding. J Dent Res 1988;67:925-931
14. Yen TW, Blackman RB, Baez RJ: Effect of acid etching on the flexural strength of feldspathic porcelain and a castable glass ceramic. J Prosthet Dent 1993;70:224-233
15. Kern M, Thompson VP: Sandblasting and silica coating of a glass-infiltrated alumina ceramic volume loss, morphology and change in the surface composition. J Prosthet Dent 1994;71:453-461
16. Isidor F, Stokholm R, Ravnholt G: Tensile bond strength of resin luting cement to glass infiltrated porous aluminium oxide cores (In-ceram). Eur J Prosthodont Restor Dent 1995;3:199-202
17. Kern M, Wenger SM: Bonding to zirconia ceramic. Adhesion methods and their durability. Dent Mater 1998;14:64-72
18. Özcan M, Alkumru HN, Gemalmaz D: The effect of surface treatment on the shear bond strength of luting cement to a glass-infiltrated alumina ceramic. Int J Prosthodont 2001;14:335-339
19. Peutzfeld A, Asmussen E: Silicoating evaluation of a new method of composite resin to metal. Scand J Dent Res 1988;96:171-176
20. Özcan M, Niedermeier W: Clinical study on the reasons for and location of failures of metal-ceramic restorations and survival of repairs. Int J Prosthodont 2002;15:299-302
21. Özcan M, Vallittu PK: Effect of surface conditioning methods on the bond strength of luting cement to ceramics. Dent Mater 2003;19:1-8
22. Zidan O, Ferguson GC: The retention of complete crowns prepared with three different tapers and luted with four different cements. J Prosthet Dent 2003;89:565-571
23. Jorgensen KH: The relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 1955;13:35-40
24. Mack PJ: A theoretical and clinical investigation into taper achieved on crown and inlay preparations. J Oral Rehabil 1980;7:255-265
25. Weed RM, Baez RJ: A method for determining adequate resistance form of complete cast crown preparation. J Prosthet Dent 1984;52:330-334
26. Dodge WW, Weed RM, Baez RJ, et al: The effect of convergence angle on retention and resistance form. Quintessence Int 1985;3:191-194
27. Nordland J, Weir D, Soffer W, et al: The taper of clinical preparations for fixed prosthodontics. J Prosthet Dent 1988;60:148-151
28. Wilson AH, Chan DC: The relationship between preparation convergence and retention of extra coronal retainers. Int J Prosthodont 1994;3:74-78
29. Walton JN, Gardner FM, Agar JR: A survey of crown and fixed partial denture failures length of service and reasons for replacement. J Prosthet Dent 1986;56:416-421
30. Dawood LM: The effect of different occlusal convergence and luting cements on the retention of extra-coronal ceramic restoration. Thesis for Master's Degree, Department of Conservative Dentistry Mansoura University, Mansoura, Egypt, 1998

31. Smith CT, Gray JJ, Conkin JE, et al: Effective taper criterion for the full veneer crown preparation in pre-clinical prosthodontics. Int J Prosthodont 1999;8:196-200
32. Haller B, Hofmann N, Nlaiber B, et al: Effect of storage media on microleakage of five dentin bonding agents. Dent Mater 1993;9:191-197
33. Ernst CP, Cohen U, Stender E, et al: In vitro retentive strength of zirconium oxide ceramic crowns using different luting agent. J Prosthet Dent 2005;93:551-558