Effects of Tooth Preparation Burs and Luting Cement Types on the Marginal Fit of Extracoronal Restorations

Mohamed F. Ayad, BDS, MScD, PhD

Assistant Professor, Section of Restorative Dentistry, Prosthodontics, and Endodontics, College of Dentistry, University of Tanta, Egypt

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Correspondence
Dr. Mohamed F. Ayad, PO Box 443, Tanta 31111, Egypt. E-mail: ayadmf@hotmail.com

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Abstract

Purpose: Although surface roughness of axial walls could contribute to precision of a cast restoration, it is unclear how the roughness of tooth preparation affects marginal fit of the restoration in clinical practice. The purpose of this study was to describe the morphologic features of dentin surfaces prepared by common rotary instruments of similar shapes and to determine their effects on the marginal fit for complete cast crowns.

Materials and Methods: Ninety crowns were cast for standardized complete crown tooth preparations. Diamond, tungsten carbide finishing, and crosscut carbide burs of similar shape were used (N = 30). The crowns in each group were subdivided into three groups (n = 10) for use with different luting cements: zinc phosphate cement (Fleck's), glass ionomer cement (Ketac-Cem), and adhesive resin cement (Panavia 21). Marginal fit was measured with a light microscope in a plane parallel to the tooth surface before and after cementation between four pairs of index indentations placed at equal distances around the circumference of each specimen. Difference among groups was tested for statistical significance with analysis of variance (ANOVA) followed by Ryan-Einot-Gabriel-Welsch Multiple Range Test ($\alpha = 0.05$).

Results: Analysis of measurements disclosed a statistically significant difference for burs used to finish tooth preparations ($p < 0.001$); however, luting cement measurements were not significantly different ($p = 0.152$). Also, the interaction effect was not significantly different ($p = 0.685$). For zinc phosphate cement, the highest marginal discrepancy value (100 ± 106 μm) was for tooth preparations refined with carbide burs, and the lowest discrepancy value (36 ± 30 μm) was for tooth preparations refined with finishing burs. For glass ionomer cement, the highest marginal discrepancy value (61 ± 47 μm) was for tooth preparations refined with carbide burs, and the lowest discrepancy value (33 ± 40 μm) was for tooth preparations refined with finishing burs. For adhesive resin cement, the highest marginal discrepancy value (88 ± 81 μm) was for tooth preparations refined with carbide burs, and the lowest discrepancy value (19 ± 17 μm) was for tooth preparations refined with finishing burs.

Conclusions: Marginal fit of complete cast crowns is influenced by tooth preparation surface characteristics, regardless of the type of luting agent used for cementation. Tooth preparations refined with finishing burs may favor the placement of restorations with the smallest marginal discrepancies, regardless of the type of cement used.

The complete veneer crown is one of the most important restorations in the armamentarium of the restorative dentist;[1] however, a clinically recognized problem is that the surface character of a prepared tooth may prevent complete seating of the crown, resulting in hyperocclusion and inadequately sealed margins[2] and local periodontal tissue inflammation.[3]

The mechanism by which metal burs remove tooth structure differs from the abrading action of a diamond rotary instrument. As burs rotate, the flutes undermine dental tissue, and the amount removed is determined by the flute angle of attack, a basic feature of bur design. In the case of diamond burs, the abrasive particles pass across the tooth surface and plough troughs in the substrate surface. Tooth structure is ejected ahead of abrading particles, and the surface is transformed into a series of ridges running parallel to the direction of the moving particles. This axial wall roughness could lead to undersized castings, because the sharp features created by the rotary instrument are not fully reproduced during successive fabrication phases: impression, die, wax pattern, investment, and casting. In addition, axial wall roughness consists of minute undercuts, which prevent removal of the wax pattern without distortion.[4] In most dental laboratories a paint-on die spacer compensates for these disadvantages and controls the thickness of the luting agent.

Although not scientifically determined, the optimal cement space dimension is considered to be 20 to 40 μm for each preparation wall.[5,6] Authors[4,7] have reported roughness measurements of teeth prepared with diamonds and carbide burs to be in this range, but determining how differences in axial roughness affect seating, retention, marginal fit, or clinical performance remains elusive. Factors of cementation pressure,[8] duration of cementation procedure,[9] powder/liquid ratio of cement,[10] preparation dimensions,[11,12] type of cement,[13] occlusal perforations,[14,15] die spacers,[16] and relief of the internal crown surface[17] have been related to cement film thickness.

Cements are used to fill the interfacial space between a fixed prosthesis and the prepared tooth, and secure the restoration in place by flowing into the surface irregularities of the tooth and the crown.[18] Traditionally, zinc phosphate cement is a luting agent that adheres by mechanical interlocking to irregularities in the tooth and casting.[19]

Newer classes of conventional glass ionomer cements, resin-modified glass ionomer cements, and resin cements have been formulated to ensure low film thickness. Conventional glass ionomer cements are used mainly because of their fluoride release, and clinical performance has been successful.[19] Moreover, cements attain their adhesion primarily through physicochemical bonding. Newer cements that are gaining popularity include the resin-modified glass ionomers, the compomers, and the adhesive resin cements. Panavia, a methacryloxyethylphenyl phosphate (phenyl-P) with Bis-GMA resin and silanated quartz, is an example of a newer adhesive luting agent.[19]

The geometry of tooth preparation has been the subject of many debates without clear evidence that one type of tooth preparation or method of fabrication provides consistently superior marginal fit.[2,4] Nevertheless, different opinions exist for the type of luting cement that might interact with such roughness.[20,21]

Marginal fit has never been strictly defined, and reference points for measurements vary considerably among clinicians; however, there are a large number of approaches to the measurement and assessment of marginal fit.[22–35] This investigation used scanning electron microscopy (SEM) to describe the morphologic features of dentin surfaces prepared by common rotary instruments, including diamond, tungsten carbide, and tungsten carbide, and finishing burs of similar shapes and to determine their effects on the marginal fit for complete cast crowns.

Materials and methods

Ninety crowns were cast for standardized complete crown tooth preparations accomplished with the use of diamond, tungsten carbide finishing, and crosscut carbide burs of similar shape (N = 30). The crowns in each group were subdivided into three subgroups of ten for the three luting cements, zinc phosphate cement, glass ionomer cement, and adhesive resin cement as follows: 90 extracted, intact human molar teeth of similar size were collected and stored in distilled water at room temperature. The teeth were prepared to simulate clinical preparations for complete crowns. Each tooth was aligned vertically in an individual polymeric tube and embedded in epoxy resin (Epoxide Resin, Leco Corp., St Joseph, MI) to within 2 mm of the cementoenamel junction.

Table 1 Rotary instruments for tooth preparations of complete crowns

Rotary instrument	Description	Catalog no.
Diamond*	Round end taper, course grit	6856 L-016
Finishing*	12-fluted round end taper	H 375 R-016
Tungsten carbide*	Crosscut round end fissure	H 33 R-016

*Brasseler Inc., Savannah, GA.

A dental surveyor was used to position the long axis of each tooth parallel to the tube. Mounted teeth were stored in an atmosphere of 100% humidity. The teeth were randomly assigned to three groups of 30 each according to the rotary instruments used (Table 1). The three rotary instruments chosen for the tooth preparations had close similarities in their taper, diameter, and tip configuration (Fig 1).

The teeth were prepared to receive complete cast crowns by flattening the occlusal surface to the depth of the central groove to expose the dentin. The reduced occlusal surface was examined with a 19-power stereoscopic microscope (SMZ-1, Nikon Inc, Garden City, NY). Additional reductions were accomplished as necessary to remove any remaining enamel. Occlusal reduction was oriented perpendicular to the axis of the polymeric tube. Axial reduction was standardized by using a milling machine (model F1, Degussa AG, Frankfurt am Main, Germany) modified to produce replicas guided by a stylized metal master model of a tooth prepared for a complete crown. An aluminum fixture was used to attach the stylus to the superior part of the machine. The stylus taper, diameter, and tip shape were machined to the same dimensions as the rotary instruments and fixed at a known distance from the cutting tools.

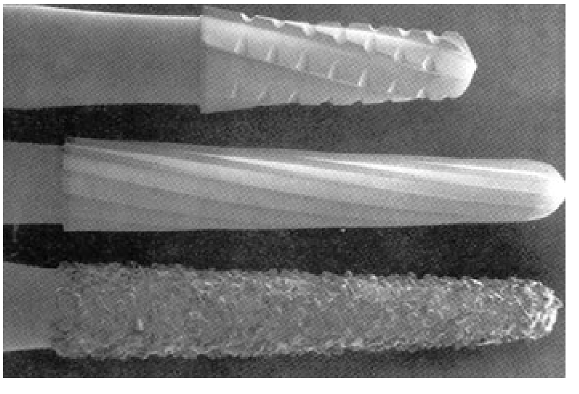
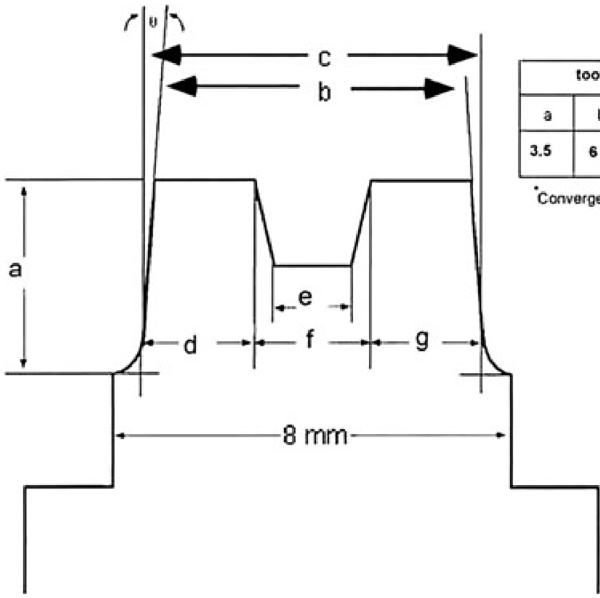


Figure 1 Rotary instruments for tooth preparations (top: tungsten carbide; middle: finishing; bottom: diamond).



tooth preparation dimension							2θ*
a	b	c	d	e	f	g	
3.5	6	7	1.9	1.2	2.2	1.9	4.6

*Convergence angle (degrees)

Figure 2 Longitudinal cross-section of master tooth preparation for a complete crown.

A movable X-Y table on the milling machine supported another fixture that secured embedded specimens at the same distance from the master tooth preparation model (Fig 2).

The apparatus operated similar to a hardware store key cutter. The teeth were prepared by moving the table and tooth assembly past the fixed portion of the machine after the tool and stylus tips were centered above the occlusal surfaces of both the tooth and the master die. All tooth preparations were initially rough cut with a diamond instrument and then refined with the randomly assigned instruments. The depth of tooth preparation was limited by a track of the stylus along the master die. The length of tooth preparation was controlled by the working height setting of the milling machine. A chamfer margin was formed as the negative image of the round-ended tapered rotary instruments. A new rotary instrument was used for each tooth, and a continuous water jet was directed at the rotary instruments. After the axial reduction, an occlusal groove was machined with a square end tapered cylinder diamond bur (Two-Striper, Abrasive Technology Inc., Westerville, OH) to develop an occlusal surface with a configuration that closely simulated actual tooth preparation. A single mix technique was used to make impressions of the prepared teeth with a poly(vinyl siloxane) impression material (Examix, GC America Inc., Chicago, IL), and the impressions were cast with type IV die-stone (Jade stone, Whip Mix Corp., Louisville, KY). A cylindrical wax pattern (Gator Wax, Whip Mix Corp.) was made for each stone die with a brass split mold. Each wax pattern was designated with a code number corresponding to the tooth from which it was derived, so that each pattern could be individually identified. The patterns were invested with phosphate-bonded investment (Cera-fina, Whip Mix Corp.) and cast with an ADA type III dental gold alloy (Ney-Oro-B2, Ney Dental International, Bloomfield, CT). Investing and casting protocol was established by pilot testing to produce crowns that seated well on the stone dies and tooth preparations with minimal force and could not be rocked or rotated. Die spacer was intentionally not used to allow the variations that existed to be maintained in the casting.

Castings were recovered from investment, bench-cooled to room temperature, cleaned in a pickling solution (Jet-Pac, JF Jelenko Co, Armonk, NY), and airborne-particle abraded with 50 μm aluminum oxide for 10 seconds with contra-angle microetcher (model erc-er, Danville Engineering, Danville, CA) at 60 psi. To minimize the effect of variations in the casting procedure, the same clinician completed all castings.

The internal surface of each casting was inspected with a $\times 20$ stereomicroscope, and minute nodules were removed with a half-round bur in a slow-speed straight handpiece. After necessary adjustment, castings fit their tooth preparations passively but were not noticeably loose or unstable. Four pairs of index indentations were placed with a half-round bur at equal distances around the circumference of each specimen; these represent mesial, lingual, buccal, and distal locations. These indentations served as specific points for determining fit differences before and after cementation. Before cementation, a spring-loaded holding device permitting axial rotation was used to secure castings on their preparations with a force of 98 N.[8,19] Using a $\times 100$ magnification light microscope (MM-11, Nikon Inc.), the position of each indentation was determined. The distance between each pair of indentations was measured in a plane parallel to the tooth surface, and the four measurements were averaged.

Castings of each group were randomly assigned to three subgroups of ten each according to the cement used, as listed in Table 2. Cements were mixed according to each manufacturer's specifications at room temperature (23°C). Zinc phosphate cement was mixed incrementally for 2 minutes on an 18 to 20°C glass slab. The powder/liquid ratio (0.5 gm/0.3 ml) was established to provide a mix that formed a 20 to 25 mm string of cement when pulled vertically from the glass slab after mixing. Panavia 21 resinous cement was mixed for 60 seconds with

Table 2 Luting cements for complete crowns

Cements	Product	Manufacturer	Lot number	P/L ratio/g
Zinc phosphate	Fleck's	Mizzy Inc., Cherry Hill, NJ	Bg8112690	0.5 g/0.3 ml
Glass ionomer	Ketac-Cem	3M ESPE, St. Paul, MN	0401281	Encapsulated
Adhesive resin	Panavia 21	Kuraray Co, Ltd., Osaka, Japan	61125	Equal length

the base dispensed in proportion to the catalyst. The prescribed coating material was applied to inhibit air during polymerization. Glass ionomer cement was activated for 2 seconds and mixed for 10 seconds in an amalgamator (Silamat, Vivadent, Amherst, NY). A stiff brush was used to coat the inner surface of each crown with an even thickness of cement. Each crown was seated with finger pressure and use of a slight back and forth axial rotation until engagement of the occlusal groove was detected. A dynamic 98 N load was applied from a force gauge (model DPP, Chatillon LTC, Greensboro, NC) through an orange wood stick placed transversely on the occlusal surface of the crown. The opposite end of the loaded stick was subjected to horizontal and vertical movement for 20 seconds, and the force was maintained for 10 minutes. Excess cement was then removed, and specimens were stored for 24 hours in 100% humidity at 37°C.

After cementation, four additional measurements on each specimen were made and averaged. The difference between the distance before and after cementation (supplemental gap) was calculated as the marginal fit for each specimen. Means and standard deviations were calculated for each group, and results were compared by a two-way analysis of variance (ANOVA) and Ryan-Einot-Gabriel-Welsch (REGWQ) multiple range test at 5% level of significance. REGWQ was used because it appeared to be the most powerful yet valid step-down multiple-stage test in the current literature.[36]

An additional tooth preparation for each rotary instrument was used to evaluate the dentin surfaces by SEM (model JSM-820, JEOL, Tokyo, Japan). Specimens were mounted on aluminum stubs and sputter-coated with gold (Desk II, Denton Vacuum, Moorestown, NJ).

Results

The ANOVA results in Table 3 demonstrate a statistically significant difference for burs used to finish tooth preparations ($p < 0.001$); however, luting cement measurements were not significantly different ($p = 0.152$). Also, the interaction effect was not significantly different ($p = 0.685$).

Table 3 ANOVA procedure for the dependent variable marginal discrepancy

Source	df	MS	*F*-value	*p*
Burs	2	2,1178.53333	6.69	<.001
Cement	2	6105.23333	1.93	.1518
Roughness * cement	4	1802.41667	0.57	.6853
Error	61	3163.6593		

df = degree of freedom; MS = mean square; *p* = probabilities.

Table 4 presents the means for each rotary instrument and luting cement separately. The data indicate that castings on tooth preparations finalized with finishing burs had lower supplemental gaps, and higher gaps were found for tooth preparations finalized with carbide burs with all three cements.

Supplemental gaps of cast crowns cemented with zinc phosphate cement on tooth preparations finalized with tungsten carbide burs (100 μm) improved by 24 to 64% compared with marginal fit on tooth preparations completed with diamond rotary instruments (77 μm) or finishing burs (36 μm). A similar comparison for crowns cemented with glass ionomer cement revealed that supplemental gaps of cast crowns on tooth preparations finalized with tungsten carbide burs (61 μm) improved by 46% compared with marginal fit on tooth preparations completed with diamond rotary instruments (33 μm) or finishing burs (33 μm). Crowns cemented with Panavia 21 resinous cement showed that supplemental gaps of cast crowns on tooth preparations finalized with tungsten carbide burs (88 μm) improved by 36 to 78% compared with supplemental gaps on tooth preparations completed with diamond rotary instruments (56 μm) or finishing burs (19 μm).

Comparing the means of all 30 specimens for each bur, REGWQ revealed a statistically significant difference ($p < 0.001$) for supplemental gaps of tooth preparations completed with tungsten carbide burs (83 ± 78 μm) and tooth preparations finalized with finishing burs (30 ± 29 μm); however, there were no differences for tooth preparations completed with diamond (55 ± 42 μm) and tungsten carbide or tungsten finishing burs regardless of the type of cement (Table 4).

The characteristic appearance of the dentinal surfaces prepared with carbide (Fig 3) and diamond (Fig 4) burs is called a pattern of galling. The fine grooves can be related to minute facets on the cutting flutes of the bur created by wear. These facets act as abrading points that scratch the dentin, resulting in the plastic deformation of the surface as the bur rotates. Specimens prepared with finishing burs (Fig 5) exhibited a smooth

Table 4 Supplemental gaps means and standard deviations among rotary instruments for each luting cement (μm)

	Tungsten carbide	Diamond	Finishing
Zinc phosphate cement (n = 10)	100 ± 106	77 ± 53	36 ± 30
Glass ionomer cement (n = 10)	61 ± 47	33 ± 39	33 ± 40
Panavia 21 cement (n = 10)	88 ± 81	56 ± 33	19 ± 17
n = 30	83 ± 78*	55 ± 42*	30 ± 29

Values with the same symbol are not significantly different at $p < 0.05$.

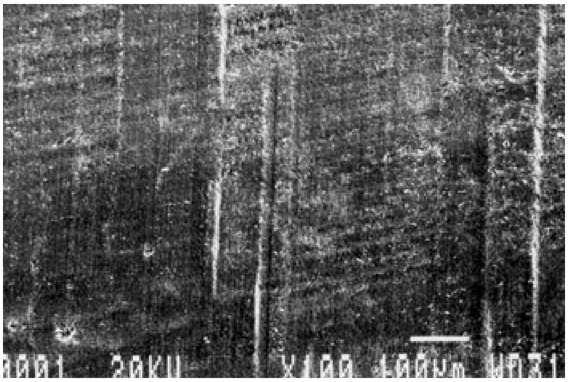


Figure 3 SEM of a tooth prepared with carbide bur. Galling pattern on the dentinal surface; grooves demonstrated a mean depth of approximately 25 μm and 150 μm between ridges.

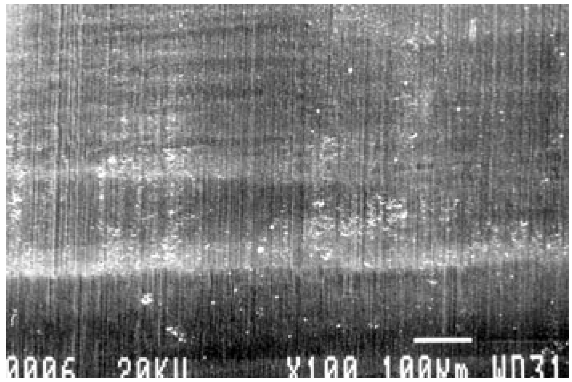


Figure 5 SEM of a tooth prepared with finishing bur. Smooth surface is evident.

surface interrupted only by slight granularity compared with greater roughness of other specimens.

Discussion

Several investigators have used metal[22] or acrylic resin[23] dies to measure marginal fit; however, steel or resin gives no real information about the microstructure of the hard tissue of the teeth after preparation or about the micromechanical and chemicomechanical adaptation of the luting cement to the dentin. In the present study, extracted teeth were used for tooth preparation. Moreover, the margin design of the tooth preparation included a chamfer finish line as recommended for the preparation of complete veneer crowns.[1]

Die-spacing techniques have specific differences for each tooth preparation technique and can affect the fit of the crown. Weaver et al[24] confirmed that the amount of die relief appeared to be a significant factor for fit. Therefore, the die spacer was not applied to the surface of the die for any of the restorations.

How marginal fit is best evaluated has never been strictly defined. Reference points for measurements and the descriptive terminology defining fit vary considerably among investigators.[25] Studies have reported measurement of fit relative to marginal adaptation, internal adaptation, vertical seating, radiographic appearance, and the clinical judgment of experienced practitioners. Alternatively, where caries is thought to be present, the appearance may be described as secondary or recurrent caries or a leaking margin.

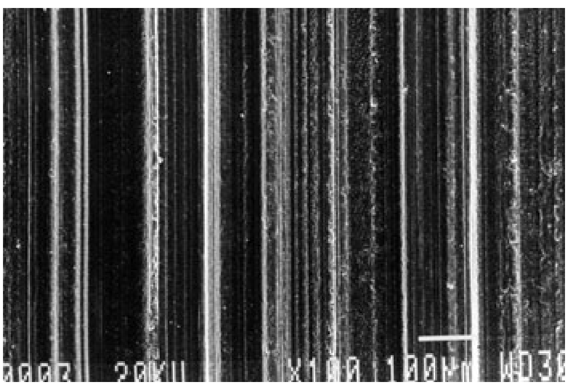


Figure 4 SEM of a tooth prepared with a diamond rotary instrument. Fine grooves running with deeper grooves having a mean depth of 15 μm and distance between ridges nearly 100 μm.

Different methods have been used to quantify marginal defects including measurement of embedded and sectioned specimens,[26] measurement of specimens or their replica by direct visualization,[27] measurement of marginal gaps before and after cementation,[23] tactile examination using an explorer, and radiographs.[28] Moreover, L'estrange et al[29] used an endoscopic microscope for evaluation of restoration margins. Others have evaluated fit as a percentage of casting oversize or undersize,[25] whereas Kay et al[30] eliminated the laboratory phase with the use of a computer simulation study. In the present study, any existing openings between the margin of the coping and the finish line of the preparation were not measured; in other words, the initial seating discrepancy was eliminated. Marginal fit of each crown was evaluated by subtracting the value between four pairs of index indentations placed at equal distances around the circumference of each specimen before and after cementation. Moreover, the restoration and tooth preparations were repositioned in identical locations. A spring-loaded holding device was used to apply a uniform load to the specimens during measurement and to precisely permit axial rotation.

Variations exist regarding what constitutes a clinically acceptable margin. Data of the present study were comparable with the results of other clinical studies that investigated the fit of single crowns before and after cementation.[22,31] An explanation of the lack of agreement may be the variation in the methods used by investigators studying marginal fit. Sulaiman et al[32] suggested that the cause could be the use of different measuring instruments. Sample size and number of measurements per specimen may also have contributed to the variation. This study showed clinically acceptable marginal fit of all groups tested.

This investigation has documented that the type of bur used to finish tooth preparations is a significant factor related to the fit of complete cast crowns. Ayad et al[4] showed that despite roughness measurements, there were statistically significant differences in the surface topography of teeth prepared for complete cast crowns ($p < 0.001$), although the recorded values for carbide burs were closer to diamond instruments than finishing burs. Regardless of the type of cement, the lowest marginal fit was achieved by finishing tooth preparations with tungsten carbide burs, and the best marginal fit was for tooth preparations finalized with finishing burs. This was explained by the smooth surface created by the finishing burs, which is interrupted only by slight granularity, compared with greater roughness of other specimens. It is theorized that a uniform thickness of cement painted over the inner surface of the crown, efficiently flowed into the spaces between projections for dentin surfaces, was not sufficient to affect the flow of cement and crown fit.

Glass ionomer cement provided the best fit with both rough and smooth tooth preparations. One explanation was that the different flow properties and film thicknesses of luting agents influenced marginal fit. This is in agreement with previous study results showing the flow rate of glass ionomer cement with a minimal film thickness of 7.24 to 20.5 μm.[8] International Organization for Standardization (ISO)[33] and American Dental Association (ADA)[34] specifications have recommended that the film thickness of zinc phosphate cement should be not greater than 25 μm; however, White and Yu[6] reported a greater film thickness of 28 μm. The film thickness of resin cement has been measured in numerous studies and found to be in the range of 31 to 45 μm.[35]

The mean of the marginal discrepancies at all measurement locations reflects the magnitude of marginal discrepancy of the entire crown; however, the marginal discrepancy of each crown may vary greatly at different locations. Because of high variation of the fit within each crown, the mean values of all measurement locations can show a large local discrepancy and result in an increase in the standard deviation (SD). Although the SDs in such studies have been reported to be approximately 20 μm,[32] the mean values of the present study were accompanied by large SDs in a range of 17 to 106 μm.

Further investigation is necessary to evaluate the effect of an artificial aging process on the marginal fit. Thermal cycling and mechanical loading are generally used to simulate oral conditions. Also, the use of fixed partial dentures rather than single crowns may result in different marginal fit values due to varied geometric forms.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1. The rotary instrument used for tooth preparations had a definite influence on the axial wall surface characteristics of complete crown preparations.
2. The interaction effect of tooth preparation finish and luting cement was not significantly different ($p = 0.685$).
3. Completing tooth preparations with finishing burs seems to improve the seating of complete crowns during the cementation procedure ($p < 0.001$).
4. Optimal marginal adaptation of cast crowns with Panavia 21 cement was recorded with tooth preparations completed with finishing burs.

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