Modern day crown preparations: an evidence based examination

Brenda Baker and **David Reaney** reveal the key principles to ensure clinical success for the treatment of various unprepared and previously prepared teeth

Education aims and objectives

This clinical article aims to present key principles to design, assess and modify complete coverage preparations to ensure clinical success for the treatment of various unprepared and previously prepared teeth.

Expected outcomes

Correctly answering the questions on page xx, worth one hour of verifiable CPD, will demonstrate that the reader understands the established clinical guidelines to optimise success and understand the biochemical implications of physical preparation.

This article aims to identify some principles that can assist dentists to design, assess and modify complete coverage preparations to ensure clinical success for the treatment of various unprepared and previously prepared teeth.

The form of prepared teeth and the amount of tooth structure removed are important contributors to the mechanical, biologic and aesthetic success of the overlying crown or fixed partial denture.

Here, the authors hope to present some established clinical guidelines to optimise success and understand the biomechanical implications of physical preparation.

The following features will be reviewed in the preparation characteristics of crowns:

1. Total occlusal convergence
2. Occlusocervical/incisocervical dimension
3. Ratio of occlusocervical/incisocervical dimension of buccolingual dimension
4. Circumferential form of the prepared tooth
5. Reduction uniformity
6. Finish line location
7. Finish line form
8. Axial and incisal/occlusal reduction depths
9. Line angle form
10. Surface texture.

Figure 1: Classic PFM margin

Figure 2: Porcelain buccal margin on PFM crown

Figure 3: Procera coping with layering porcelain

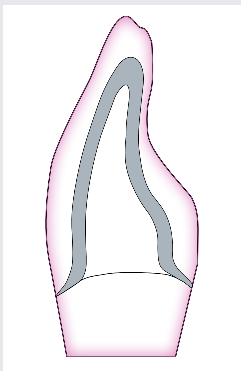

Figure 4: Even labial reduction required to maximise aesthetics

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Total occlusal convergence

Total occlusal convergence (TOC) is the angle formed between two opposing prepared axial surfaces. Shillingburg and colleagues recently suggested that the TOC should be between 10 and 22 degrees (1997).

Therefore, during clinical tooth preparation, the use of a mirror has been

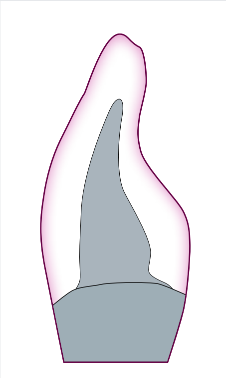

Figure 5: All-ceramic crown outline

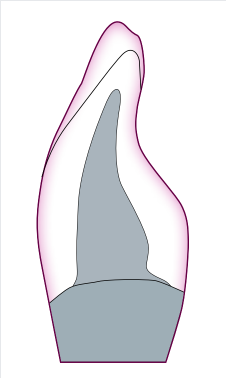

Figure 6: Incisal 'cut back' for addition of translucent porcelain

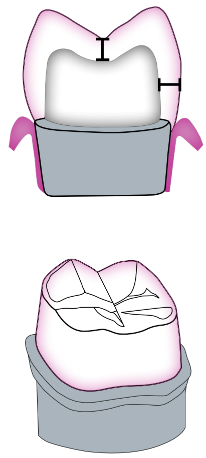

Figure 7: Posterior preparation requires adequate axial and occlusal reduction

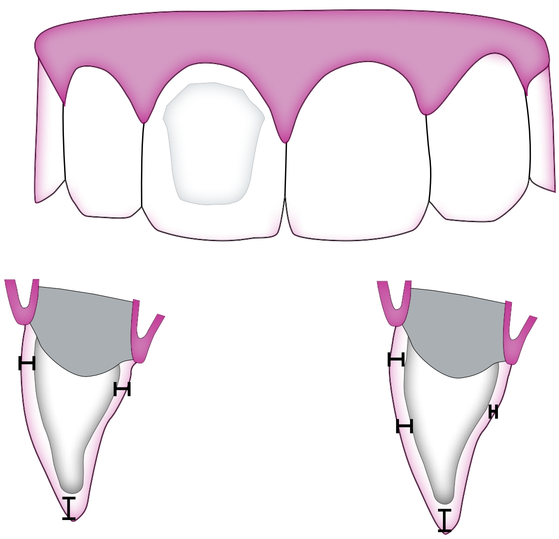

Figure 8: To maximise aesthetics and strength of restorative material on anterior teeth, adequate reduction is essential

recommended so that a facial or lingual view of the prepared teeth is established. Facial/lingual clinical views are the most effective means of assessing TOC because convergence of mesial and distal surfaces is readily visible (Goodacre, 2004).

> *'Facial/lingual clinical views are the most effective means of assessing TOC because convergence of mesial and distal surfaces is readily visible'*

The literature has also presented data on several factors likely to create greater TOC and perhaps even necessitate the formation of auxiliary characteristics that enhance resistance to dislodgement.

1. Posterior teeth are prepared with greater TOC than anterior teeth (Annersledt et al, 1996; Norlander et al, 1988)
2. Mandibular teeth are prepared with greater convergence than maxillary teeth (Smith et al, 1999; Kent, Shillingburg and Duncanson, 1988)
3. Mandibular molars are prepared with the greatest TOC (Leempoel et al, 1987)
4. Buccolingual surfaces have greater convergence than mesiodistal surfaces (Annersledt, 1996). However, Kent and colleagues determined that mesiodistal convergence was greater than buccolingual convergence (1988)
5. Fixed partial denture (FPD) abutments are prepared with greater TOC than individual crowns (Mack, 1980)
6. Monocular vision (one eye) creates greater TOC than binocular vision (both eyes) (Mack, 1980). In the presence of the factors that increase TOC beyond the recommended 11° to 20° range, it is recommended that auxiliary tooth preparation features such as grooves or boxes be added to enhance the resistance of restorations to dislodgment.

Occlusocervical/incisocervical dimension

It has been proposed that anterior teeth and premolars have a minimal occlusocervical (OC) dimension of 3mm, and that molars have a minimal dimension of 4mm. Critical convergence angles have been mathematically calculated and used to identify angles beyond which a crown would theoretically not possess adequate resistance to dislodgement (Parker et al, 1988; Parker et al, 1993).

An assessment of the resistance form of dies from clinically failed restorations supported a relationship between convergence angles and clinical failure, as reported by Trier and colleagues (1998).

The resistance of crowns made for dies the size of prepared incisors and premolars has been tested, and it was concluded that 3mm provides adequate resistance (Maxwell, Blank and Pelleu, 1990), supporting the recommended OC dimension for premolars and anterior teeth.

The tipping resistance of molar-sized crowns has also been measured by Woolsey and Matich (1978). Three millimetres of OC dimension provided adequate resistance but only at a TOC of 10°. Three millimetres was inadequate at a 20° TOC, an angle frequently found on molars.

Teeth lacking these minimal dimensions should be modified to enhance their resistance form through formation of proximal grooves/boxes.

Ratio of occlusocervical/ incisocervical dimension to buccolingual dimension

The ratio of the OC dimension to the buccolingual (BL) dimension should be 0.4 or higher for all teet; 96% percent of incisor crowns, 92 % of canine crowns, and 81% of premolar crowns possess adequate resistance despite variations in their preparation form and dimension – however, only 46% of molars possess appropriate resistance, as found by Parker and colleagues (1991).

When anterior teeth are prepared for complete coverage crowns, they usually possess a favourable ratio between the incisocervical crown dimension and the mesiodistal/buccolingual dimension.

Molars have less favourable ratios between the OC dimension and the BL dimension than anterior teeth. When mandibular molars are prepared they have a rectangular form with rounded corners that enhance resistance form.

Circumferential form of the prepared tooth

Teeth should be prepared so they possess circumferential irregularity whenever possible. When teeth are anatomically reduced, they possess characteristic geometric forms. For instance, when prepared maxillary molars are viewed occlusally, they have a rhomboidal form. Mandibular molars have a rectangular form and most premolars and anterior teeth have an oval form. These shapes produce circumferential irregularity. The value of these irregularities has been evaluated by comparing the resistance areas of conical and pyramidal tooth preparation. The pyramidal preparation provided increased resistance, as shown by Hegdahl and Sillness (1977). Therefore, it is important to preserve the 'corners' of a tooth preparation whenever possible.

When prepared teeth have no corners due to their round morphologic form or existing condition, they should be modified by forming axial grooves or boxes that provide resistance to dislodging forces. As molars are frequently prepared with greater convergence angles than other teeth, and because they usually have a smaller OC dimension and less favourable OC/BL dimension ratio, they often benefit from axial grooves or boxes.

It is suggested that axial grooves/boxes be routinely used when mandibular molars are prepared for bridgework. Chewing and parafunctional habits place dislodging forces on single crowns and fixed partial dentures that are largely BL in direction, auxiliary resistance form features should be located in the tooth where they provide optimal resistance to these forces.

Proximal grooves provided complete resistance to FL crown dislodgment, whereas facial or lingual grooves provide only partial resistance (Woolsey and Matich, 1978). Therefore, auxiliary resistance form features such as grooves and boxes should be located on the proximal surfaces of fixed partial denture abutments.

Reduction uniformity

Teeth should be uniformly reduced, thereby enhancing the potential for normal crown form and an improved aesthetic result.

Reduction uniformity is best achieved by placing depth grooves into the surface to be reduced and then reducing the tooth in accordance with the grooves.

Table 1: Seven key principles of preparation (derived from Shillingberg)

Seven space key principles	Function
Conservation of tooth tissue	To avoid weakening the tooth unnecessarily To avoid compromising the pulp
Resistance form	To prevent dislodgement of a cemented restoration by apical or obliquely directed forces
Retention form	To prevent displacement of cemented restoration along any of its paths of insertion, including the long axis of the preparation
Structural durability	To provide enough space for a crown that is sufficiently thick to prevent fracture, distortion or perforation
Marginal integrity	To prepare a finish line to accommodate a robust margin with close adaptation to minimise microleakage
Preservation of the periodontium	To shape the preparation such that the crown is not overcontoured and its margin is accessible for optimal oral hygiene
Aesthetic considerations	To create sufficient space for aesthetic veneers where indicated

Table 2: Suggested preparation features for posterior crowns

Crown type posterior crowns – preparation features	
Occlusal reduction*: Finish line depth and configuration	
Full contour crowns (FCC) – metal or zirconia	
Full contour crowns (FCC) – metal or zirconia • 1mm non-functional cusps • 1.5mm functional cusp	• 0.3-0.5 mm • Chamfer, knife-edge, shoulder or shoulder with bevel
High strength all-ceramic (HSAC) (veneered) or monolithic lithium disilicate • 2mm non-functional cusps • 2.5mm functional cusps	• 1.0 mm shoulder or heavy chamfer
Porcelain fused to metal (PFM) – as for FCC if metal occlusal • 2mm non-functional clasps • 2.5mm functional cusps	• 1.2mm labial shoulder+ or chamfer • 0.5mm lingual chamfer (metal collar) • 0.5mm lingual chamfer (metal collar) • 1.2mm circumferentially of 360 degree ceramic margin

* Where tooth is tilted or where vertical dimension it to be increased is to be increased, the amount of occlusal reduction required will vary

+ Too deep a reduction for diminutive teeth or for long clinical crowns where a metal collar is preferable.

Finish line location

Finish lines should be positioned equi- or supragingivally (Valderhaug and Birkeland, 1976) whenever the aesthetic and resistance form requirements permit such a location.

However, subgingival finish lines are often used for appropriate reasons that include the need to achieve adequate OC dimension for retention and resistance form, to extend beyond caries, fractures, and erosion/abrasion, or to encompass a variety of tooth structure defects.

Subgingival finish lines are also used to produce a cervical crown ferrule on endodontically-treated teeth and to improve the aesthetic result achieved on discoloured teeth. Periodontal health can be retained when subgingival margins are used if other factors must be present. The restorations must be properly contoured and exhibit good marginal fit, as shown by Brandau, Yaman and Molvar (1988).

Table 3: Suggested preparation features for anterior crowns

Crown type: Anterior crowns – Preparation features	
Occlusal reduction*: Finish line depth and configuration	
All-ceramic (veneered or monolithic) (AC) • 2mm incisally • 1mm lingual aspect	• 0.8-1.0mm shoulder
Resin bonded porcelain crowns (RBPC) • 2mm incisally • 0.5-1.0mm lingual aspect	• >0.4mm chamfer
Porcelain fused to metal (PFM) • 2mm incisally • 0.5-1.0mm lingual aspect (Porcelain guidance requires greater clearance)	• 1.2mm labial shoulder+ or heavy chamfer • 0.5mm lingual chamfer • 1.2mm circumferentially for 360° ceramic margin
*Where the vertical dimension is to be increased, the amount of occlusal reduction required will be less or non-existent +Too deep a reduction for diminutive teeth, for example, lower incisors or for long clinical crowns where metal collar is preferable	

When a subgingival finish line is required, multiple studies indicate that extension to the level of the epithelial attachment should be avoided. Pocket deepening does not occur when the margin is at least 0.4mm occlusal to the depth of the gingival crevice (Waerhaug, 1953) whereas more severe gingivitis occurs when subgingival margins approximate the depth of the crevice (Newcomb, 1974).

In one study, when teeth were prepared so provisional crown margins were located farther apically than recommended, about a millimetre of gingival recession was noted within two weeks and little over 1mm of recession was recorded within eight weeks. Histologic evaluation indicated the recession mechanism was activated during the first seven days according to Tarnow and colleagues (1986). When crown margins were extended to the bone crest, 1mm of crestal bone loss was observed (Carnevale, Sterrantino amd Di Febo, 1983).

Finish line form

All-metal crowns

Chamfer finish lines have been frequently used for all-metal crowns. No scientific studies have stated that chamfers are superior to other finish lines. However, they are used with all-metal crowns because they are easy to form with a tapered, round-end diamond instrument and because they are distinct, being readily visible on the prepared tooth, impression and die.

Chamfers also possess adequate bulk for restorative rigidity and their depth is sufficient to permit the development of normal axial contours. Recommended chamfer depth is determined by the minimal metal thickness for strength and minimal space required to develop a physiologic emergence profile. Dykema, Goodacre and Phillips (1986), as well as Malone and Koth (1989) have recommended chamfer finish line reduction depths of 0.3 to 0.5mm.

It is recommended that chamfer finish lines for all metal crowns possess a minimum depth of approximately 0.3mm (Goodacre, 2004).

Metal-ceramic crowns

The following types of finish line have historically been used with metal ceramic crowns: chamfer, bevelled chamfer, shoulder and bevelled shoulder. Recommended metal-ceramic finish line depths are based on the minimal material thickness required for strength and aesthetics as well as the minimal space required to develop a physiologic emergence profile. A thickness between 1.0 and 1.5mm for the porcelain-veneered marginal area of a metal-ceramic crown has been suggested (Shillingburg et al, 1997; Dykema, Goodacre and Phillips, 1986; Malone and Koth, 1989; Rosentiel, Land and Fujimoto, 1995; Chiche and Pinault, 1994).

Multiple studies have indicated that at least 1.0mm of translucent porcelain (not including metal and opaque) is required to reproduce the colour of a shade guide (Douglas and Przybylska, 1999), which indicates that tooth reductions in excess of 1.0mm are needed.

All-ceramic crowns (veneered and monolithic lithium disilicate)

Chamfer finish lines produced lower strength with non-bonded crowns in laboratory tests (Craig, El-Ebrashi and Peyton, 1967). However, the negative effect was not replicated when the crowns were bonded (internally etched crowns cemented to etched prepared teeth with resin) to the teeth (Tjan and Sarkissian, 1986).

It therefore seems appropriate to recommend shoulder finish lines for all-ceramic crowns that are not to be bonded to underlying tooth structure, whereas chamfer or shoulder finish lines can be used when the crowns are to be bonded.

All-ceramic crowns (monolithic zirconia)

This new generation restoration can be finished with any of the traditional methods: chamfer, bevelled chamfer, shoulder and bevelled shoulder. Recommended finish line depths are based on the minimal material thickness required for strength and aesthetics as well as the minimal space required to develop a physiologic emergence profile. Authors and manufacturers have recommended thicknesses between a minimal 0.4 mm and 1.0mm for the marginal area of this monolithic all zirconia crown.

Axial and incisal/occlusal reduction depths

The required depth of reduction varies with different types of crowns and various surfaces of a tooth. Reduction is also affected by the position and alignment of teeth in the arch, occlusal relationship, aesthetics, periodontal considerations and tooth morphology. Deep occlusal interdigitation of posterior teeth or appreciable vertical overlap of the anterior teeth often necessities greater overall reduction of occluding surfaces. Malaligned teeth have commonly required greater reduction of protruding surfaces to permit restoration alignment and/or satisfactory retention and resistance form.

Periodontal health is enhanced through the development of normal cervical crown contours, but overcontoured restorations promote plaque accumulation.

All-metal crowns and monolithic zirconia all-ceramic crowns should have chamfer depths of at least 0.3mm, axial surface reductions of at least 0.5 to 0.8mm, and occlusal reduction depths of 1 to 1.5mm (Goodacre, 2004). For metal-ceramic crowns, depths of 1.0mm or more have been proposed and are aesthetically desirable for the finish line and buccal reductions. Finish line (greater than 1.0 mm) and buccal reductions depths of 1.5-2.0mm are recommended for veneered and monolithic zirconia all-ceramic crowns and monolithic lithium disilicate crowns. An incisal/occlusal reduction of 2mm for all-ceramic crowns permit the development of appropriate colour, strength, translucency and morphology.

All-metal crowns and monolithic zirconia crowns

For all-metal crowns and monolithic zirconia crowns, finish line depths of 0.3 to 0.5mm have been recommended (Dykema, Goodacre and Phillips, 1986; Rosentiel, Land and Fujimoto, 1995). For all-metal crowns and fixed partial dentures, there are no data that identify the ideal axial reduction depths. At least 0.5 to 0.8mm of reduction is recommended by clinicans and laboratory technicians, to be developed near the occlusal aspect of the buccal and lingual surfaces. This depth of reduction provides adequate space for the development of normal axial contours and material thickness for strength. Proximal reduction should include the formation of a distinct finish line and provide access for impression making.

> *'The inherent colour of the abutment tooth can influence the colour of the overlying all-ceramic crown, requiring greater ceramic thickness when the dentine is discoloured*

A minimum of one millimetre of occlusal reduction provides space for the fabrication of these crowns, but reduction depths of 1.5mm provide the space whereby well-defined occlusal grooves and convex ridges can be developed.

Metal-ceramic crowns

Finish lines for metal ceramic crowns should be 1.0 to 1.5mm deep and the buccal surface be reduced between 1.0 and 1.7mm (Shillingburg et al, 1997; Dykema, Goodacre and Phillips, 1986; Rosentiel, Land and Fujimoto, 1995; Chiche and Pinault, 1994). These recommendations are supported by research from Douglas and Przybylska, who determined 1.0mm or more of translucent porcelain is required to reproduce shade guide specimens (1999).

When aesthetic materials are to be placed over incisal/occlusal surfaces, reduction depths of 2.0 to 2.5mm have been recommended for metal-ceramic restorations to provide space for the development of appropriate colour, anatomic form, and occlusion (Shillingburg et al, 1997; Dykema, Goodacre and Phillips, 1986; Malone and Koth, 1989; Rosentiel, Land and Fujimoto, 1995).

All-ceramic veneered crowns and monolithic lithium disilicate crowns

All-ceramic finish line depth recommendations range from 0.5 to 1.0mm (Shillingburg et al, 1997; Dykema, Goodacre and Phillips, 1986; Malone and Koth, 1989; Rosentiel, Land and Fujimoto, 1995; Chiche and Pinault, 1994). From a buccal surface reduction perspective, there is little improvement in shade matching when the thickness of veneered all-ceramic crowns or monolithic lithium dislicate all-ceramic crowns is increased beyond 1mm with semi-translucent, all ceramic systems (eg, e.max or Empress Esthetic) and high value, low- chroma shades (eg, A1) (Douglas and Przybylska, 1999).

However, thicknesses in excess of 1mm are beneficial when using more opaceous all-ceramic systems (Lava 3M Espe or Calypso SCDL) or when using lower value, more chromatic shades such as C2 and A3 (Douglas and Przybylska, 1999). The inherent colour of the abutment tooth can influence the colour of the overlying all-ceramic crown, requiring greater ceramic thickness when the dentine is discoloured.

Line angle form

Line angles are formed when prepared tooth surfaces meet each other. Sharp line angles create stress concentration, as reported by Craig, El-Ebrashi and Peyton (1967). Line angles should be rounded during tooth preparation to enhance strength and minimise crack propagation, especially in all-ceramic veneered restorations and monolithic lithium disilicate crowns. The purpose of rounding line angles with all-metal and metal-ceramic crowns is related more to facilitating laboratory procedures and optimising fit than enhancing restoration strength.

Round line angles facilitate the fabrication of gypsum casts from impressions without trapping air bubbles as well as the investment of wax patterns without air inclusions. Trapped air bubbles can lead to nodules in castings that impede complete seating of a restoration. Casting nodules also are easier to remove when the line angles are rounded during tooth preparation.

Surface texture

Tooth preparation should be reasonably smooth to enhance restoration fit.

Tooth preparation smoothness (Tjan and Sarkissian, 1986) has been found to improve the marginal fit to restorations in two studies, whereas another study found no difference in the marginal seating of complete crowns when the axial surfaces were prepared with coarse diamond instruments (120um grit size) and when they were prepared with fine diamond (50um grit size) instruments.

Summary

The following guidelines are proposed when preparing teeth for compete crowns and fixed partial dentures:

1. The TOC (angle of convergence between opposing prepared axial surfaces) should range between 10° and 20°. However, posterior teeth are frequently prepared with greater convergence angles, as are fixed denture partial denture abutments. When the TOC angles exceed the recommended levels, the tooth preparation should be modified to include auxiliary features such as grooves or boxes

2. Three millimetres should be the minimal occlusocervical/incisocervical (OC/IC) dimension of incisors and premolars when they are prepared within the recommended TOC range of 10-20 degree. The minimal OC dimension of molars should be 4mm when prepared with 10-20 degree TOC. When the OC dimension is less than the recommended dimension, the tooth preparation should be modified to include auxiliary features such as grooves or boxes

3. The ratio of the OC/IC dimension to the BL dimension should be 0.4 or higher for all teeth. When this ratio is not present, as on large diameter molars, the tooth preparation should be modified to include auxiliary features such as grooves or boxes

4. Teeth should be prepared in a manner that preserves the buccoproximal and linguoproximal corners whenever possible because circumferential irregularities enhance resistance form. When prepared teeth lack 'corners' and are round after tooth preparation, they should be modified to include auxiliary features such as grooves or boxes

5. When auxiliary features are placed into teeth, the preferred locations are the proximal surfaces. The buccal/lingual surfaces are secondary locations to be used when the addition of proximal features leaves the tooth in a state of questionable resistance form. Proximal grooves/boxes should routinely be used when mandibular molars are prepared for bridges because mandibular molars often are prepared with the greatest TOC and frequently have limited OC dimension and large FL dimensions that lead to unfavourable ratios

6. For the purpose of optimising periodontal health, finish lines should be located equi- or supragingivally when the condition of the tooth and aesthetic requirements permits such a location. When subgingival finish lines are required, they should not be extended to the epithelial attachment

7. For all-metal or fully monolithic zirconia all-ceramic crowns, a minimum 0.3mm deep chamfer finish lines should be used. The axial and occlusal reduction depths for all-metal crowns should be at least 0.5mm and 1.0mm, respectively

8. For metal-ceramic crowns, finish line selection should be based on formation ease, personal preference, aesthetic requirements and the type of crown being fabricated rather than on expectations of enhanced marginal fit with one type of finish line compared with the others. Many teeth, because of available tooth structure thickness external to the pulp, cannot be reduced facially to depths that exceed 1mm

9. Shoulder finish lines are recommended for all-ceramic crowns when they are not bonded to the underlying tooth. However, shoulder and chamfer finish lines can be used with all-ceramic crowns that are bonded to the prepared tooth using a resin cement and acid etching. Finish line and facial reduction depths greater than 1mm are not required when using a semi-translucent type of all-ceramic crown but are beneficial when more opaceous porcelain systems are used or when the tooth structure is discoloured. Incisal/occlusal reduction depths of 2mm are achievable due to the available thickness of tooth structure.

10. Rounded line angles on tooth preparations for all-ceramic crowns decrease the stress placed on the crowns and thereby increase crown longevity. With crowns that contain metal (all-metal and metal-ceramic crowns), line angles are rounded to facilitate pouring impression and investing wax patterns without trapping air bubbles and to facilitate the removal of casting nodules

11. Tooth preparation smoothness seems to enhance restoration fit, but its effect on retention appears to be related to the type of cement used. Surface roughness generally increased retention with zinc phosphate cement, but no definitive relationship has been established when crowns are cemented with adhesive cements (eg, polycarboxylate, glass ionomer, resin).

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Round line angles facilitate the fabrication of gypsum casts from impressions without trapping air bubbles as well as the investment of wax patterns without air inclusions

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