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Optimizing resin cement removal around esthetic crown margins

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Abstract

Objective. To quantify luting cement at the crown–tooth interface of esthetic crowns fabricated using four different techniques and two methods of excess cement removal. ***Material and Methods***. Four methods of crown fabrication were used: the feldspathic porcelain and platinum foil technique, the feldspathic porcelain and refractory die technique, the resin composite crown and CAD/CAM technique, and the feldspathic porcelain crown and CAD/CAM technique. Half of the cemented crowns were allocated to Group A: removal of excess cement by flicking-off with a plastic instrument 3 min after initial polymerization, or Group B: removal of excess cement using a wiping action with cotton pellets. Morphologic measurements, using non-destructive digital profilometry, were made of the volume of excess cement (mm^3), mean maximum and mean depth of excess cement (μm), and surface area of excess cement (mm^2). ***Results***. ANOVA and Duncan post-hoc tests revealed no statistical differences ($p < 0.05$) between the four types of crown fabrication with respect to volume and mean depth of retained luting cement. There was a significantly greater volume, mean depth, and mean maximum depth of luting cement retained using the "flick off" method compared to the cotton pellet "wiping" method for excess cement removal, but no statistical differences in mean surface area between the two methods. ***Conclusions***. Following removal of excess luting cement, as judged clinically, using two methods, subclinical amounts of cement remained adherent to the tooth surface of all specimens at the crown–tooth interface.

Key Words: *All-ceramic crowns, CAD/CAM, excess cement, luting cements*

Introduction

Esthetic metal-free crowns are an extension of the porcelain veneer concept. Like veneers, they can be constructed on a refractory model or on a platinum foil matrix, as well as through computer aided design/computer aided manufacturing (CAD/CAM). Their use is increasing as more patients request metal-free restorations.

Esthetic crowns require adhesive bonding to the tooth using resin composite luting cements. These cements have superior retention, reduced dissolution in the oral environment, and the ability to reduce microleakage [1–3] compared with other luting materials. In addition, they are color-matched to tooth structure to provide an esthetic restoration. However, this factor, combined with the relative inaccessibility of the approximal surfaces and gingival crevices and complex root surface topography at the crown–root interface, makes removal of excess cement very difficult [4]. Cement retention on the tooth surface is likely to result in plaque accumulation, leading to gingivitis and perhaps root surface demineralization.

In the literature, excess luting cement following cementation of esthetic crowns has been removed using several methods, two of the most popular being wiping with a cotton pellet directly after cementation and "flicking-off" with a hand instrument or scalpel after initial polymerization of the luting cement.

Crocker [5] removed excess cement first with a number 15 scalpel blade and then with superfine diamond points, extra-fine tungsten carbide 12-bladed burs and flexible abrasive disks. Crothers et al. [6] suggested that before polymerizing any excess luting cement should be removed with a sable brush moistened in unfilled resin, as this gives a better marginal finish than polishing. They stated that cotton pellets 'drags out' the unset cement. After

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polymerizing, they advised that any excess cement should be removed using fine diamond burs, followed by abrasive silicon points and abrasive disks, and finishing with diamond polishing paste.

Burke & Watts [7] removed excess luting cement with sponge pellets and, after polymerization, any remaining excess was removed with a 30-μm grit diamond finishing bur. Burke [8] further described removing the excess cement using a probe and dry brush tip; after polymerization, abrasive rubber points, aluminum oxide polishing paste and diamond polishing paste were used.

There are very few articles investigating whether excess cement remains adherent to the tooth surface after removal of excess luting cement. Mitchell et al. [4] used profilometery to compare excess cement retention around different types of metallic and porcelain crowns and found that excess cement remained adherent at the crown margins and in any developmental grooves or concavities. However, there are no articles in the literature quantifying the amount of excess cement remaining adherent to the tooth surface dependent on the method of fabrication of specifically metal-free esthetic crowns.

Traditionally, these crowns are constructed using either the platinum foil or the refractory cast techniques. In the foil technique, platinum foil is burnished onto the cast, and after crown fabrication the foil is removed prior to crown cementation. In the refractory technique the master cast is duplicated in a refractory material, and after crown fabrication the adherent refractory material is sand-blasted away. It is difficult to estimate or control the amount of porcelain removed during this procedure.

Computer aided design/computer aided manufacturing (CAD/CAM) is an alternative method of fabricating dental restorations. An optical impression of the prepared tooth is produced electronically and the geometry of the prosthesis is designed by dedicated computer software. The crown is then fabricated by milling a material blank in a milling machine. The blanks may be constructed of different types of ceramic; for example, Cerec Mark II (Vita, Germany) or a polymer composite material such as Paradigm MZ100 (3M ESPE, St. Paul, Minn., USA).

These different methods of fabricating esthetic crowns have the potential to influence the amount of excess cement remaining adherent at the crown margins following cement clean-up. Different methods of esthetic crown fabrication lead to variations in marginal fit and cement space thickness [9–14]. However, it is unknown presently if these variations alter the quantity and distribution of excess cement remaining around esthetic crown margins.

Therefore, the aims of this study were to compare the amount of resin composite luting cement left adherent on the tooth surface following removal of excess cement, as judged clinically, between the cotton pellet wiping and "flicking-off" methods of excess cement removal, using non-destructive digital profilometry. The research hypothesis was that there were significant differences in the amount of resin composite luting cement left adherent on the tooth surface following removal of excess cement dependent on the method of cement removal and/or on the method of crown fabrication.

Material and methods

Preparation of specimens

Forty human premolar teeth were prepared for full-coverage esthetic crowns and randomly allocated to one of four groups of crown construction. The teeth were embedded in autopolymerizing polymethyl methacrylate resin (Ortho Resin; Dentsply, Weybridge, UK), within 12-mm diameter brass cylinders. Standardized crown preparations, as described by Mitchell et al. [9], were performed with either a diamond chamfer bur (Hi-Di, No. 613; Henry Schein Rexodent, Southall, UK) for the platinum foil and the refractory die methods, or a diamond shoulder bur (Hi-Di, No. 546; Henry Schein Rexodent) for the CAD/CAM method, mounted in an air rotor with water coolant, while the tooth specimens were held in the 3-jaw chuck of a mini-lathe (Unimat 3; Emco, Atlanta, Ga., USA). Teeth were prepared with 6-degree axial taper with the crown margin placed at the amelocemental junction. The specimen was then mounted in a low-speed saw (Isomet; Buehler, Coventry, UK) and the occlusal surface cut flat, perpendicular to the long axis of the tooth at a height of 4 mm. All line angles were rounded by hand with a fine silicon carbide disk.

The 40 prepared teeth were randomly allocated to 1 of 4 experimental groups:

- Group 1: Feldspathic porcelain (PVS; Skillbond Direct, High Wycombe, UK) esthetic crowns constructed using the platinum foil technique.
- Group 2: Feldspathic porcelain (PVS; Skillbond Direct) esthetic crowns constructed using the refractory die technique.
- Group 3: Esthetic crowns constructed using a resin composite (Paradigm MZ100; 3M ESPE) and utilizing the CAD/CAM technique (CEREC; Sirona Dental Systems, Bensheim, Germany).
- Group 4: Esthetic crowns constructed using feldspathic porcelain (Vitablocs Mark II; Vita Zahnfabrik, Bad Sackingen, Germany) and utilizing the CAD/CAM technique (CEREC; Sirona Dental Systems).

Polyvinyl siloxane impressions (Express; 3M ESPE) were recorded of each preparation with a

putty-wash one-stage impression technique using a stock tray. The impressions of the prepared teeth were then cast in die stone material (Vel-Mix; Kerr UK Ltd., Peterborough, UK). On setting, impressions were separated from the dies and excess stone material was removed with carbide trimmers and rubber wheels.

In groups 1 and 2, the dies were painted with stone die and plaster hardener resin (George Taub Products, Fusion Co. Inc, Jersey City, N.J., USA) to maximize surface hardness. In group 1 (platinum foil group), the crown matrices were constructed directly on the die using 0.019-mm-thick "Platinum Foil" (SkillBond Direct). The crowns were constructed using feldspathic porcelain (PVS, SkillBond Direct).

In group 2 (refractory die), the dies were painted with two layers of die spacer and duplicated in refractory die material (VHT; SkillBond Direct). The crowns were similarly constructed using feldspathic porcelain (PVS; SkillBond Direct). After the porcelain was fired (Table I), the refractory material was removed by sandblasting with 50-μm aluminium oxide beads at a pressure of 3 psi. The crowns in these two groups were checked for thickness at 6 points: center of buccal, lingual, mesial, and distal surfaces, and the cusp tip of the buccal and lingual cusps, to ensure a standardized thickness of 1 mm axially and 2 mm occlusally at the cusp tip for all crowns.

In groups 3 and 4 (CAD/CAM technique) the CEREC 3 machine (Sirona Dental Systems) was used. To mill crowns with this system, the prepared tooth required to be positioned between two adjacent teeth (mesially and distally). Otherwise, if the die was of an individual tooth the software would mill a coping, rather than the full-coverage crown desired. For this reason, the dies for groups 3 and 4 were individually mounted in a soft-acrylic upper arch cast (Viade Products, Camarillo, Calif., USA) in the position of the upper right 2nd premolar.

Construction of crowns using the CEREC 3 machine involved the following steps: powdering the cast (Vita Powder; Vita Zahnfabrik, Bad Sackingen, Germany), selection of type of restoration, and tooth number. A digital camera recorded an optical impression, encircling the outermost circumference of the neighboring teeth. The exact finish line for the restoration was traced by one operator. The orientation of the crown and height of the approximal marginal ridges was determined on the basis of the neighboring teeth fissures. The CEREC software automatically calculated the height and position of the cusp apices. Cross sections of the designed crown were then viewed to ensure adequate thickness, equal to those of groups 1 and 2, fabricated by hand. The milling button operation was activated and size 10 blocks of the resin composite (Paradigm; 3M ESPE) and size 10 of feldspathic porcelains (Vitablocs Mark II) were prepared to the required shape for groups 3 and 4, respectively.

Following fabrication, the fit of each crown to the corresponding prepared tooth was assessed visually and with a dental probe and all crowns were judged to be a satisfactory clinical fit.

Each crown was cemented to assess the retention of excess luting cement after crown cementation. Groups 1, 2, and 3, were cemented with a resin composite luting cement (RelyX ARC; 3M ESPE) and Group 4 with the resin composite luting cement recommended for cementation of that porcelain (Variolink II; Ivoclar-Vivadent, Liechtenstein). The cementation procedure involved following the manufacturer's instructions regarding silanation, etching, priming, and bonding, as described in Table I. A standard volume (0.1 ml) of cement was mixed and applied by one operator in an even layer to the dentin of the tooth and the fitting surface of the crown. The crown was then cemented under a standard force of 30 N [15]. This force was applied to the midpoint of the central fissure on the occlusal surface using an indentor with a spherical 2-mm diameter tip held in a jig. Half of the cemented crowns from the three groups were allocated to Group A: removal of excess cement by "flicking-off" with a plastic instrument after 3 min of initial polymerization, and half to Group B: removal of excess cement using a "wiping" technique with cotton pellets. The load of 30 N was held in position for 10 min before profiling was carried out. The clean-up procedures were carried out for a standard time of 90 s.

Table I. Sequence of tooth and crown preparation for the two cements

RelyX ARC	Variolink II
Apply RelyX ceramic primer to fitting surface of crown, dry 5 s	Apply Monobond-S ceramic primer to fitting surface of crown, leave 60 s, dry 5 s
Dry the tooth 5 s	Dry the tooth 5 s
Apply etching gel 15 s, rinse 10 s, dry 2 s	Apply etching gel 30–60 s, rinse, dry 2 s
Apply 2 layers of Scotchbond 1 adhesive to the tooth surface, dry 5 s, light-polymerize 10 s	Apply Syntac primer to the tooth surface 15 s, dry for 5 s
	Apply Syntac adhesive to tooth surface, 10 s, dry for 5 s
Mix base and catalyst and apply cement to prepared tooth and fitting surface of crown	Apply Heliobond bonding resin to both crown fitting surface and tooth surface
	Mix and apply cement to prepared tooth and fitting surface of crown

Profilometry of specimens

The mesial surface of the crown–tooth interface was profiled twice, with 40 profiles of each surface recorded at 100 μm apart. Profile 1: The tooth with the crown seated and held in place by a standard load of 5 N, but not cemented. Profile 2: Profile of the tooth with the crown seated, cemented, and excess luting cement removed by one of the two methods described above.

Profiling was carried out at the Minnesota Dental Research Center for Biomaterials and Biomechanics, University of Minnesota, using a null point contact tungsten carbide stylus, as described previously [4,16,17].

A standard surface area of 12 mm^2 was identified, centered on the midpoint of the mesial surface of each tooth, along 3 mm of the crown–root interface and extending 2 mm apically and coronally on either side. Morphologic measurements were made of the volume of excess cement (mm^3), mean maximum and mean depth of excess cement (μm), and surface area of excess cement (mm^2).

Statistical analysis was carried out using analysis of variance and Fisher's PLSD test to determine if statistical differences ($p < 0.05$) existed, dependent on method of crown fabrication or method of cement removal.

Results

Inspection of the individual profiles of the crown–margin interface, generated by the AnSur NT software from the data acquired by the profilometer, showed that the cotton pellet tended to scoop excess retained luting cement from under the crown margin, while use of a dental instrument ("flick-off method") caused the excess cement to break away cleanly from the surface of the tooth. This was supported by the descriptive statistics for volume, surface area, mean and maximum depth of excess cement for each method of excess cement removal presented in Table III.

Statistical analysis of the data was carried out using SPSS (V13.0; SPSS UK, Woking, UK). The data for volume of retained cement were subjected to a cube root transformation and mean depth of retained cement a square root transformation prior to carrying out ANOVA. No transformations were required for the mean maximum depth and surface area data. Analysis of variance indicated significant differences (significant F value) between groups ($p < 0.05$), and Duncan post-hoc tests indicated where differences existed between groups.

Table II gives the descriptive statistics and results of ANOVA for retention of excess cement parameters by crown fabrication type. It showed that there were no significant differences between the different methods of crown fabrication for volume or mean depth of retained cement. However, the crowns fabricated from resin composite or feldspathic porcelain, using the CAD/CAM method, retained significantly higher mean maximum depth and surface area of cement than the feldspathic porcelain crowns fabricated by either the platinum foil or refractory die techniques. There were no significant differences in mean maximum depth or surface area of retained cement between the two groups fabricated using the CAD/CAM method or the two groups fabricated by conventional techniques.

In Table III, ANOVA showed that the "flick-off" method gave significantly higher volume, mean depth, and mean maximum depth of excess retained cement than the wiping with a cotton pellet method. However, there was no significant difference in surface area of excess retained cement between the two methods of cement removal (Table III).

The rankings from greatest to least amount of cement retention, for each method of crown fabrication, are listed in Table IV.

Table II. Descriptive statistics and results of ANOVA for retention of excess cement measurements by crown type. SD = standard deviation, MV = mean value

Excess cement parameter	Method of removal	Volume (mm^3)	Mean depth (μm)	Mean maximum depth (μm)	Surface area (mm^2)
Feldspathic porcelain and platinum foil	Flick off (MV±SD)	0.15±0.21	26.88±11.01	116.32±78.67	0.37±0.29
	Cotton pellet (MV±SD)	0.03±0.07	11.96±7.89	53.15±43.33	0.66±0.23
	Total (MV±SD)	0.08 a±0.15	18.35 a±11.62	80.22 a±64.36	0.53 a±0.28
Feldspathic porcelain and refractory die	Flick off (MV±SD)	0.11±0.12	17.88±7.38	78.92±19.48	0.79±0.20
	Cotton pellet (MV±SD)	0.003±0.00	10.31±6.31	67.32±41.25	0.61±0.18
	Total (MV±SD)	0.07 a±0.11	15.04 a ±7.6	74.57 a±27.19	0.72 a ±0.20
Resin composite and CAD/CAM	Flick off (MV±SD)	0.20±0.22	24.60±15.03	175.60±64.73	1.24±0.57
	Cotton pellet (MV±SD)	0.004±0.00	16.07±13.27	131.01±43.78	0.97±0.17
	Total (MV±SD)	0.10 a±0.18	20.33 a±14.10	153.30 b±57.15	1.10 b±0.42
Feldspathic porcelain and CAD/CAM	Flick off (MV±SD)	0.21±0.15	27.22±14.15	245.33±142.45	0.79±0.40
	Cotton pellet (MV±SD)	0.07±0.08	12.81±7.04	152.96±117.71	0.87±0.17
	Total (MV±SD)	0.13 a±0.12	19.22 a±11.6	194.01 b±122.38	0.83 b±0.29

Groups with different letters (a or b) indicate significant differences $p < 0.05$).

Table III. Descriptive statistics and ANOVA of excess cement by removal method. SD = standard deviation

Method of removal	Excess cement parameter	Volume (mm^3)	Mean depth (μm)	Mean maximum depth (μm)	Surface area (mm^2)
Flick off	Mean value ± SD	0.17 a ± 0.16	23.64 a ± 11.27	153.11 a ± 94.94	0.85 a ± 0.48
Cotton pellet	Mean value ± SD	0.03 b ± 0.06	13.13 b ± 8.81	107.91 b ± 79.80	0.80 a ± 0.22

Groups with different letters (a or b) indicate significant differences $p < 0.05$).

Discussion

In this study, two methods were used to remove excess resin composite luting cement after crown cementation. The results indicated that for esthetic crowns‘wiping-off the excess luting cement with a cotton pellet left a significantly smaller volume, mean depth, and mean maximum depth of luting cement compared with “flicking-off” the excess luting cement with a plastic hand instrument. However, there was no statistical difference in surface area between the two methods. The findings may be interpreted clinically that, when using the “flicking-off” method the cement breaks cleanly away from the surface of the tooth, whereas the cotton pellet method tends to drag the partially-set cement from under the crown margin. Thus the “flick-off” method would result in a larger retained volume of cement with a greater mean and mean maximum depth, but a similar surface area between the edge of the crown and the edge of the preparation. The clinical significance of this is the preference that any concavity at the crown–tooth margin, because of marginal misfit, be smoothly filled with luting cement, rather than be left as a concave niche for plaque accumulation.

The use of a contact profilometer in this study enabled “before” and “after” images to be aligned using dedicated software which takes the point data of the “before” and “after” images and performs a least-squared fit, permitting super-imposition of the images. Differences between the image discrepancies can then be assessed. The accuracy of the system is ±7 μm out to a 60° incline. The software also provides digitally rendered images of the crown–root interface surfaces, thus aiding visual interpretation of the results. The tendency for the cotton pellet method to drag cement out from beneath a crown margin was therefore easily identified.

It may be anticipated that the amounts of excess cement remaining adherent to the root surface, following standardized clean-up protocols, in this laboratory-based study, under ideal conditions of visibility and access would be less than those left adherent clinically. In addition, the quantity and distribution of the adherent excess cement will be greatly influenced by the individual operator. The effect of this excess retained cement around the crown margins on periodontal health is currently unknown.

Inspection of Table II shows that not all of the results were normally distributed and therefore data transformation was required prior to carrying out analysis of variance testing. The data for volume of retained cement were subjected to a cube root transformation and mean depth of retained cement, a square root transformation, prior to carrying out ANOVA. No transformations were required for the mean maximum depth and surface area data.

A standard volume of cement was used to coat the inner surfaces of each crown and the tooth preparation prior to it being seated with a standard load on each prepared tooth. The amount of excess cement expressed from around the crown margins will be dependent on the viscosity and flow of the luting cement, and the thickness of the cement space for each type of crown. The viscosity of the cement is influenced by the presence of diluent monomers and the time elapsed since the start of the mix. A low cement viscosity will ensure a low film thickness and good seating of the crown on the preparation; however, it may also make it more difficult to clearly identify and remove the unwanted excess cement as it will flow more readily from around the crown margins.

The significantly greater mean maximum depth and surface area of retained excess cement observed for crowns fabricated using the CAD/CAM method, compared to conventional fabrication on a refractory or foiled die, may be a reflection of the superior marginal fit found for crowns fabricated using conventional refractory of foil techniques.

Table IV. Ranking of excess cement parameters

Ranking	Volume (mm^3)	Mean depth (μm)	Mean maximum depth (μm)	Surface area (mm^2)
Greatest amount	Mark II	Paradigm	Mark II	Paradigm
	Paradigm	Mark II	Paradigm	Mark II
	Platinum foil	Platinum foil	Platinum foil	Refractory die
Least amount	Refractory die	Refractory die	Refractory die	Platinum foil

Conclusions

Following cementation of esthetic crowns, fabricated using four different techniques, and removal of all excess luting cement as judged clinically, subclinical amounts of cement remained adherent to the tooth surface of all specimens at the crown–tooth interface. There were no statistical differences between the four methods of crown fabrication with respect to volume and mean depth of retained luting cement. In addition, there was a significantly greater volume and mean depth and mean maximum depth of luting cement retained using the "flick off" method compared to the "wiping" cotton pellet method for excess cement removal, but there were no statistical differences in surface area between the two methods. This study indicated that this difference occurred because the cotton pellet tended to drag the unset cement from under the crown margin, while the "flick-off" method of removing partially polymerized cement tended to fracture the excess cement flush with the crown–tooth margin.

The research hypothesis of this study was therefore accepted.

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