ORIGINAL ARTICLE

INFLUENCE OF DIFFERENT LUTING AGENTS ON THE MARGINAL DISCREPANCY OF PROCERA® ALLCERAM ALUMINA CROWN COPINGS – AN EXPERIMENTAL STUDY

Shriharsha Pilathadka, Radovan Slezák, Dagmar Vahalová, Marina George Kudiyirickal, Sujith Sukumar

Charles University in Prague, Faculty of Medicine and University Hospital Hradec Králové, Czech Republic: Department of Dentistry

Summary: Two maxillary first molars and two central incisor typhodont teeth were prepared with 0.8 mm chamfer, 2.0 mm occlusal reduction, and 6 degree taper. The prepared teeth were duplicated 9 times to obtain 36 die stone models and divided into three groups (n = 12). Luting agents tested were zinc phosphate, glass ionomer and resin cement. Procera®AllCeram 0.6 mm coping was fixed with a calibrated finger force of 50 N. The absolute marginal discrepancy was measured using the scanning electron microscope on four axial walls with 4 measurements on each wall to obtain a total of 16 readings for one tooth. Mann Whitney U test was applied to find significant differences between luting cements and Kruskal Wallis tests among groups. Results The absolute marginal discrepancies of cements were in reducing order zinc phosphate (AZ) 53 μm; resin (AR) 44.5 μm, glass ionomer (AG) 29 μm. There was a significant difference among luting cements AG V/s AZ (p = 0.001) and AR V/s AG (p = 0.003), except AR V/s AZ (p = 0.213). All axial surfaces except mesial showed a significant difference. Conclusion The study concluded that different luting media have a definite effect over the final fit of AllCeram coping. Absolute marginal discrepancy was within the accepted level of 100 μm. Distal axial surface demonstrated a wider gap among all the luting agents.

Key words: *AllCeram alumina copings; Luting cements; Absolute marginal discrepancy*

Introduction

The Procera® system (Nobel Biocare, Gothenburg, Sweden) had conceived the idea and developed the computer assisted designing/computer assisted manufacturing (CAD/CAM) based production of the substructure for indirect all-ceramic restorations since 1994 by Oden and Anderson (2). Since its development, it has undergone several technical upgradations in its application. There are only a few CAD/CAM systems around the world which provide the dentist with in-house (laboratory/clinic) scanning and designing facility using contact scanner and distant production facility to realise this virtual electronic data into physical form (2). The accuracy of this Procera® contact scanner was confirmed to be close to 10 μm (22). AllCeram material is one of the materials produced by Nobel Biocare Gothenburg, Sweden and used as substructure material for tooth and implant supported crown and bridge prosthesis. Five, six and 10 year survival rates were 97.7 %, 94.3 % and 93.5 % respectively (19, 28, 20). The published success rate is within the global success standard for new dental materials (23). The attractive advantage of high strength all-ceramic substructure for metallic substructure is the fact that all-ceramic copings are translucent (9) and allow the reflected light to pass through the crown. It has become the first choice of clinicians to prescribe for patients with versatile aesthetic demand.

The marginal integrity of CAD/CAM produced indirect all-ceramic crowns is very critical for its long term durability in the complex oral environment, along with aesthetics and fracture resistance (13). There were numerous studies conducted on Procera® AllCeram crown to investigate the marginal discrepancy of crown material *in vitro* and *in vivo* (1, 6, 8, 14–16, 19, 24). All these studies employed different methods like direct tactile inspection and visual inspection using scanning electron microscope, epoxy replicas, stereomicroscope, and other aids. The majority of these studies compared the marginal discrepancy of AllCeram crown copings with other all-ceramic systems and found an acceptable marginal gap width of 100 μm (17) and minimal marginal gap for cemented AllCeram crown copings (1, 6, 8, 14–16, 19, 24).

Due to the high fracture resistance of AllCeram crowns, the use of conventional cements and resin based cements without any pre-treatment of fitting surface has been suggested (2). It was further supported that fitting surface

AllCeram coping has microroughness due to the manufacturing process. This microroughness was found to be an additional aid for the retention of the crown with luting cements (2).

The role of luting agents in cementation of fixed partial denture is to flow into the irregularities of the tooth and fitting surfaces of the crown. The excess cement flows out effectively, so that a minimal amount of luting media will be exposed to the oral cavity and with minimal elevation of the crown. Post cementation elevation of the crown was investigated and proved in *in vitro* with metallo-ceramic crowns (29). The very nature of this junction can be an influencing factor for survival of the crown (18, 27). However, there are a few other confounding cement and cementation factors which can directly or indirectly affect the final fit of the crown (31). With AllCeram crown copings, Neart et al. did notice the elevation of the coping but did not find any influence of different luting agents over the marginal discrepancy (19). Conventional cements like zinc phosphate cement, with all-ceramic crowns, showed the beneficial effect over the final aesthetics of the crown by masking underlying discolouration of the abutment tooth (4). However, physical properties and chemical composition of conventional cements differ substantially from resin cements and require additional clinical procedure to achieve the final cementation.

Given the clinical situation of the increased use of Procera® AllCeram crowns and multiple different luting agents, the primary objective of this study was to investigate the absolute marginal discrepancy of cemented Procera® AllCeram crown copings with more commonly used but inherently different luting agents in clinically simulated laboratory conditions. The secondary objective was to find out whether different axial surfaces would differentially affect the marginal discrepancy. Circumferential direct marginal investigation with scanning electron microscope (SEM) imaging was considered.

Materials and Methods

Tooth preparation

Two maxillary right central incisors and first molar typhodont teeth (AG 3, Frasaco, Germany) were prepared for Procera® AllCeram crown according to the manufacturer's instruction, using All-ceram crown preparation set (Meissinger, Hager&Meissinger GmbH, Hansenmannstr, Neuss, Germany). All the teeth were prepared with a uniform width of 0.8 mm of circumferential chamfer finish line fol-

Tab. 1: Details of the cementing medias used.

Cementing media	Group	Manufacturer	Lot number
Zinc phosphate cement (Adhesor®)	AZ	Spofa Dental, A Kerr Company, Czech Republic.	CE 0044 Powder – 1238736–3; Liquid – 1343558
Glass ionomer cement (Kavitan®Cem)	AG	Spofa Dental, A Kerr Company, Czech Republic.	CE 0044 Powder – 1585904; Liquid – 1550335–2
Resin cement Dual®Cement	AR	Ivoclar Vivadent AG, Schaan, Liechtenstein.	CE 0123 Base – G0 6570; Catalyst – GO 6570

Tab. 2: Cementation procedure with luting medias.

Cementation with zinc phosphate cement (AZ group) and glass ionomer cement type 1 (AG group)
• Fitting surface of the copings were cleaned with isopropyl alcohol and air dried. • 2 scoops: 5 drops of P/L ratio was dispensed on to frozen glass slab and mixed in conventional manner till the desired luting consistency (frozen glass slab tq) at a room temperature. • Thin layer of cement was coated onto the fitting surface of coping using micro brush ((Ivoclar Vivadent AG, Schaan, Liechtenstein) [Ishkiriama tq] (12). • Copings were rotated from lingual to buccal surface during seating onto the respective die model using finger force of 50 N for 5–8 minutes (Salter, Czech Republic). • Excess flash is cleaned around the margin. • Tactile and visual inspection of the margin was performed using an explorer (EXD 11/12, Hu-Friedy, USA).
Cementation with resin cement (AR group)
• Fitting surface of the copings were cleaned with isopropyl alcohol and air dried. • The base and catalyst were dispensed to equal length on a mixing pad and manually mixed with plastic spatula to uniform colour and spread over a large area. • A thin layer of the cement was applied to the fitting surface of the copings. • Coping were rotated from lingual to buccal surface and seated onto respective die models using finger force of 50 N. • Excess cement was removed quickly by wiping with cotton pellet. • The cement was light cured around the margins for about 40–60 seconds on each axial surface. • Tactile and visual inspection of the margin was performed using an explorer (EXD 11/12, Hu-Friedy, USA).

lowing the course of the gingiva, 2 mm of occlusal reduction with 6 degrees of occlusal convergence under copious water spray. Labial surface of the incisors and buccal surface of the molars were prepared with two-plane reduction. On molars, occlusal surface were prepared non-anatomically, without having the deep areas. Functional cusps were beveled of a 45 ° angle to the long axis of the tooth. All the sharp line angles and edges were smoothened and finished with 30 µm rotary instruments. Silicone matrices (Speedex, A-silicone material Coltene Whaledent, Sweden) were used to control the uniform reduction of the tooth three dimensionally.

Impression and fabrication of die

Four prepared teeth were mounted on individual self cured resin blocs (Primacryl® Plus, Spofa Dental, Czech Republic) 2–3 mm away from the chamfer finish line. The mid point of individual axial surfaces were scribed onto the base of the resin block 4 mm below the gingival finish line on the mid-buccal, mid-mesial, mid-lingual and mid-distal surfaces using a Bard Parker blade no-11. Using a custom made acrylic impression tray and additional silicon impression material, two steps putty wash technique (Aquasil™ soft putty and, Aquasil Ultra LV, Dentsply DeTrey, Germany) was employed to make an impression of the original models. The impressions were poured using the type 4 die stone (Japan stone, Dr Böhme and Schöps Dental GmbH, Goslar, Borsigstrasse) to obtain 36 die stone models. These models were checked for any defect, and coated with a die hardening solution (Hardening Bath, Renfert GmbH, Germany). Three sets of four original tooth preparations were allotted into three groups of 12 teeth.

Fabrication of Procera® AllCeram copings

The master dies were prepared for scanning according to the manufacturer's instruction with parallel sided below. Prepared master dies were scanned using a contact scanner at the Department of Dentistry, Faculty of Medicine, Hradec Králové, Czech Republic (Procera® Piccolo scanner, serial No 34666, Nobel Biocare, Gothenburg, Sweden) to obtain the digitized image of the master dies. These virtual data were processed using Procera® CAD design software version 1.6 (Nobel Biocare, Gothenburg, Sweden). The predetermined 50 µm cement space was incorporated into the coping during the designing stage to accommodate the space for cementing media. The ordered coping thickness was 0.6 mm of white alumina coping. The scanned data were transferred to the production centre at Nobel Biocare Gothenburg, Sweden. These data were used in the production facility to mill the enlarged refractory die onto which high purity alumina powder was pressed and sintered at 1550 °C for 1 hour (2).

Cementation of Alumina copings

We employed commonly used conventional cement zinc phosphate (Adhesor®, Spofa Dental, Czech Republic), glass ionomer cement (Kavitan®Cem, Spofa Dental, Czech Republic) and resin cement (Dual®Cement, Ivoclar Vivadent AG, Schaan, Liechtenstein) as luting media. The details of the cementation technique are summarized in Tab. 2.

Evaluation of marginal adaptation in SEM imaging

Circumferential direct marginal evaluation of the cemented specimens was conducted for AllCeram copings on die stone models using scanning electron microscope imaging (Leica Leo S 440 I, Leica Cambridge Ltd, Cambridge, England, UK). All the specimens were prepared for viewing in SEM by desiccating and sputter coating with 50 nm of gold palladium alloy in sputter coater (Model SC 7640, Poloron, Quarium technologies Sussex, UK) for 4 minutes. All axial surfaces were first viewed for the pre-indented mid axial surface. Four more potential measuring sites were selected at an interval of 200 µm along the marginal finish line on each axial surface for a total of 16 readings for each individual tooth. The width of absolute marginal discrepancy was measured using a pre-calibrated electron-measuring bar of SEM, which depicts the actual marginal width in microns taking the magnification factor into consideration. The sensitivity of this electron-measuring bar was calculated beforehand and was found to be 0.02 µm. A single SEM operator measured the absolute marginal discrepancies of all the samples. The measuring accuracy of the operator was ascertained by measuring the known dimensions to eliminate the possibility of inducing variation during the measurement. A pilot study with metallo-ceramic crown coping was performed at the beginning of this study to master the laboratory procedures and measuring methods in SEM.

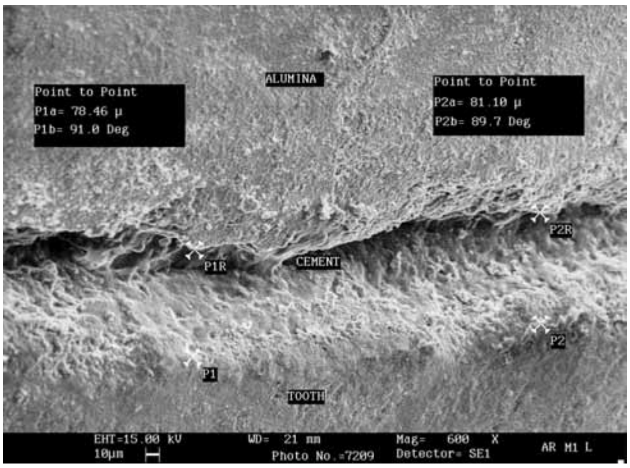

Fig. 1: SEM microphotograph demonstrating the measurement of marginal discrepancy.

Statistical analysis

The marginal width in the SEM was measured from the edge of the finish line to the alumina copings. The means of four measurements of the individual axial surfaces (mid-labial, mid-mesial, mid-lingual, and mid-distal) were calculated. Using the mean of all the four axial surfaces, the absolute marginal discrepancy of the individual tooth was computed. Employing this data, a mean absolute marginal discrepancy for each individual study group was calculated. The results were averaged (mean $\pm$ standard deviation) for each parameter. The Mann Whitney U test was applied to find out the significant difference between the two independent groups. Kruskal Wallis test was applied to find out the significant difference between the study groups. In all the above tests, $p \leq 0.05$ was considered to be statistically significant. The data was analysed using SPSS software package (SPSS for windows, SPSS Software Corp, Chicago, USA).

Results

The mean values of absolute marginal discrepancy of Procera® AllCeram crown copings using three different luting media, independent of the tooth types are summarized in Table 3. On the mid-buccal surface there were significant differences between the AR and AZ (p = 0.007) and AG and AZ (p = 0.014). On the mid-lingual surface significance differences were shown between AR and AG (p = 0.003), AG and AZ (p = 0.020) groups. On the mid-distal surface there was significance between AR and AG group (p = 0.010) but between AR and AG (p = 0.128) group. However, on the mid-mesial surface there was no significance between all the study groups. Thus it was confirmed that there was a significant effect of the type of luting agent used on the marginal discrepancy of Procera® AllCeram crown copings when compared at all four axial surfaces.

Subsequently, the effect of luting cements over the mean absolute marginal discrepancy of the tooth was compared. This analysis showed that there was a significant difference (p = 0.001) between the three luting cement groups over the mean marginal discrepancy. Specific luting media comparisons are presented in Table 4. This confirmed the overall positive effect of luting agents over the mean absolute marginal adaptation.

Tab. 3: Absolute marginal discrepancy on individual axial surface (median value in μm) and result of intergroup comparisons on respective axial surface ($p \leq 0.05$).

Axial surface	Zinc phosphate cement	Glass ionomer cement	Resin cement	p value
Mid – buccal	61.15	38.86	41.54	0.01
Mid – mesial	41.60	30.41	40.77	0.10
Mid – lingual	49.88	20.77	55.98	0.01
Mid – distal	53.37	32.95	48.15	0.02
Circumferential	53.37	29.30	44.72	0.00

Tab. 4: Circumferential absolute marginal discrepancy comparison between luting media ($p \leq 0.05$).

Comparison of group	z value	p value
Zinc phosphate V/s Resin cement	- 1.27	0.219
Glass ionomer cement V/s Resin cement	- 2.89	0.003
Glass ionomer cement V/s Zinc phosphate cement	- 3.18	0.001

Discussion

The marginal accuracy of the cemented crown is of clinical importance and influences long-term survival of the restorations. In this study the parameter used for the measurement of the marginal misfit was absolute marginal discrepancy. This is an angular combination of the marginal gap and an extension in the vertical and horizontal direction. According to Holmes et al. (11), the consideration for measurement of absolute marginal discrepancy should be measured from the margin of the casting to the cavosurface angle of the chamfer preparation. Furthermore, the absolute marginal discrepancy would reflect the total misfit of the crown at a given spot around the margin.

During the crown cementation procedure, there is complete filling of the cement space, which is provided during the designing stage of CAD/CAM crowns or bridges. The cementation should bring about minimum marginal discrepancy and minimal elevation of the crown in the occlusal direction. To achieve this, the excess cement has to be expelled out by seating force. Different amounts of seating force and methods have been recommended for seating of metallo-ceramic crowns and bridges (29, 31).

The conventional cementation technique is an accepted method of cementation for all-ceramic crowns and bridges (2). Zinc phosphate cement is the oldest luting agent and thus has the longest track record. It can serve as the standard by which newer luting systems can be compared (3). This cement provides retention by mechanical bonding onto the irregularities of the tooth and fitting surface. The intaglio surface of the Procera® AllCeramic crowns has an inherent micro-roughness (2, 7, 32) which can provide additional mechanical interlocking with zinc phosphate cement. Type 1 glass ionomer has excellent biological advantages compared to resin cements, in addition to chemico-mechanical bonding. Glass ionomer cement showed moderate translucency (26) in comparison with all-ceramic crowns. However, the final shade of the cement can be selected. Study of microleakage from Albert et al. (1) determined that Procera® AllCeramic crowns demonstrated moderate microleakage (49 %) with glass ionomer cement when compared with other luting cements. Resin based composite cements are the material of choice for adhesive luting of all-ceramic crowns with small clinical crowns. Dual activated cements are a popular alternative to the other resin based cements because it has a long handling time and the operator has a choice of selecting the shade of the cement. In the absence of light activation, the presence of the chemical activator alone ensures a high degree of polymerization. Aesthetic benefits are also excellent along with minimal microleakage around the crown margin (1).

In the present study, the effect of luting cements over the absolute marginal discrepancy of the Procera® AllCeram copings was compared. The result of this study showed a significant difference (p = 0.001) between the three luting cement groups over the mean marginal gap of the Procera® AllCeram copings. There were significant differences between the AR and AG (p = 0.003), AG and AZ (p = 0.001) groups, with the exception of the AR and AZ group (p = 0.219). This confirmed the overall positive effect of luting agents over the mean absolute marginal adaptation of Procera® AllCeram copings.

The absolute marginal discrepancy values of our study (n = 12) were found to be in the reducing order, i.e., zinc phosphate cement (53 μm), resin cement (44 μm) and glass ionomer cement (29 μm). The conventional cementing media demonstrated better marginal discrepancy than resin cement. Furthermore, we compared our results with the result of Quintas et al. (12), who documented that there was no significant effect of the luting cement over the vertical marginal discrepancies of Procera® AllCeram copings. In the same study, they presented the vertical marginal discrepancy after cementation in the reducing order, i.e., glass ionomer cement (46 μm), resin cement (45 μm) and zinc phosphate cement (41 μm). These results are in partial agreement with the current study results.

Naert et al. (19) found in their study that the luting media did not affect the marginal fit. They concluded that the marginal gap was increased after the cementation of the coping and they asserted that this situation was the clinical reality. Beschnidt et al. (5) compared the marginal adaptation of five different types of all-ceramic crowns and they concluded that cementation increased the marginal discrepancy. They also added that neither conventional cementation nor adhesive cement had an effect on the marginal discrepancy.

In the present study, the type of the cementation force used was static finger pressure of 50 N with standardization. This procedure was comparable to the clinical situation. However, the static force may not have been powerful enough when compared to the dynamic force (25) and ultrasonic vibration to transform the highly viscous luting agents into low viscosity under the present experimental conditions. This could have prevented the complete marginal adaptation of the copings with zinc phosphate and resin cement group.

It has been proved by further study of the CAD/CAM produced all-ceramic partial crowns that high viscosity luting agents resulted in larger marginal interfacial widths than the low viscosity luting agents (17). The conditions in which the present experiment was conducted were not close to the clinical conditions in simulating the direct bonding of the resin cement to the tooth structure because we used the die stone models instead of natural teeth, which would have influenced the final interpretation of the experimental value of the AR group.

In the present study, the zinc phosphate cement (AZ) group demonstrated the highest absolute marginal discrepancy of 53 μm in comparison to the other groups. Zinc phosphate cement produced the greatest peak of hydrostatic pressure in the centre of the occlusal surface (10). This was further supported by the studies of Wilson (29, 30), who suggested the venting of the crowns in order to relieve the stress concentration of cast crowns. This could also be partially responsible for the wider absolute marginal discrepancy of the AZ group. Yu et al. (31) also asserted that there is a definitive interaction between the type of cement used and the cementation technique. While this investigation was not a comparison of the cementation technique, there was a fundamental focus to measure the marginal gap of Procera® AllCeram crown copings. We also cannot exclude the fact that the type of luting media that we used also has a very different film thickness and different rheological properties under pressure (21). This could be attributed to the different flow properties of these cements. That could be the reason that we have different marginal discrepancy values with the aforementioned luting media.

When we consider the interrelationship between the marginal opening and marginal leakage of all-ceramic crown with the type of cement, there are few studies which confirm that luting agents did not influence marginal adaptation. Furthermore, it proved that zinc phosphate had the highest amount of microleakage and the least was with adhesive composite resins. A similar study with Procera® AllCeram crowns documented a significant association between cement type and microleakage (1). The study results in reducing order, zinc phosphate 76 %, glass ionomer 49 %, resin modified glass ionomer 10 % and resin cement 34 %. The mean value however, of the marginal adaptation of all the cements used in his study was 54 μm, while in our study value was 42 μm.

In the Procera System, the cement space provided is 50 μm thick. This space is uniform and extends up to 1 mm short of the cavosurface margin of the finish line (19). The function of the die spacing is to provide the space for the cementing media, thereby reducing the stress concentration during cementation of the crowns. This space is a predetermined setting by the manufacturer and can be incorporated during the design stage of the coping.

The study of marginal fit and internal adaptation of the Procera® AllCeram copings found that the wider internal gap (occlusal) width favoured the small marginal gap dimension (6, 14). Study by Quintas et al. (24) postulated that since the cement space was greater in AllCeram coping, the luting agents might have flowed more quickly during cementation procedure. In comparing the results of our investigation with other investigations, evidence suggests that the mean absolute marginal adaptation of the Procera® AllCeram crown coping with all three cementing media was within the biologically acceptable measurement, which is 100 μm.

Further research should focus on an increased number of specimens to evaluate the marginal adaptation and with a natural teeth sample to understand the effect of chemical bonding of resin cements. Furthermore, measuring the internal gap of the samples with the same methodology would disclose the total quantification of the 'misfit' of Procera®AllCeram crown coping. In addition, clinical study employing different luting media should be conducted to evaluate the very nature of the post-cementation marginal fit of Procera®AllCeram crown coping.

Conclusion

Within the parameters of this study it can be concluded that Procera® AllCeram crown copings:

1. Absolute marginal adaptations were within the biologically acceptable limits of 100–120 µm regardless of type of luting cements.
2. The statistically significant difference ($p \leq 0.05$) in absolute marginal gap size as a function of the difference in axial surface was confirmed.
3. Mid-buccal & mid-distal surfaces showed the highest & most variable marginal gap size.
4. Glass ionomer cement showed a significantly smaller and uniform marginal gap.
5. Marginal discrepancy with luting agents in reducing order glass ionomer cement, resin cement, and zinc phosphate cement.

Acknowledgment

This project was funded by the Department of Dentistry, Faculty of Medicine, Hradec Králové, Czech Republic. The authors would like to express sincere thanks to Martina Bohuňovská, (Reg-Pharma, s.r.o, Czech Republic) and Nobel Biocare (Gothenburg, Sweden) for providing us the technical support.

References

1. Albert FE, El-Mowafy OM. Marginal adaptation and microleakage of Procera AllCeram crowns with four cements. Int J Prosthodont 2004;17(5):529–35.
2. Andersson M, Oden A. A new all-ceramic crown: a dense-sintered, high-purity alumina coping with porcelain. Acta Odontol Scand 1993;51:59–64.
3. Anusavice KJ. Philips' Science of dental materials. 10th ed. Philadelphia, WB Saunders 1998:566.
4. Barath VS, Faber F-J, Westland S, Niedermeier W. Spectrophotometric analysis of all-ceramic materials and their interaction with luting agents and different backgrounds. Adv Dent Res 2003;17:55–60.
5. Beschnidt SM, Strub JR. Evaluation of the marginal accuracy of different all-ceramic crown systems after simulation in the artificial mouth. J Oral Rehabil 1999;26;582–93.
6. Bindl A, Mormann WH. Marginal and internal fit of all-ceramic CAD/CAM crown-copings on chamfer preparations. J Oral Rehabil 2005;32:441–7.
7. Blatz MB, Sadan A, Kern M. Resin-ceramic bonding: a review of literature. J Prosthet Dent 2003;89:268–74.
8. Boening KW, Wolf BH, Schmidt AE, Kastner K, Walter MH. Clinical fit of Procera AllCeram crowns. J Prosthet Dent 2000;84(4):419–24.
9. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas M, et al. Relative translucency of six all-ceramic systems. Part 2: Core and veneer materials. J Prosthet Dent 2002;88:10–5.
10. Hoard RJ, Caputo AA, Contino RM, Koenig ME. Intracoronal pressure during crown cementation. J Prosthet Dent 1978;40:520.
11. Holmes JR, Bayne C, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthet Dent 1989;62:405–408.
12. Ishikiriama A, Oliveira Jde F, Vieira DF, Mondeli J. Influence of some factors on the fit of cemented crowns. J Prosthet Dent 1981;45(4):400–4.
13. Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent 1996;75:18–32.
14. Kokubo Y, Ohkubo C, Tsumita M, Miyashita A, Volt Von Steyern P, Fukushima S. Clinical marginal and internal gaps of Procera AllCeram crowns. J Oral Rehabil 2005;32:526–30.
15. Lin MT, Sy-Munoz J, Munoz CA, Goodacre CJ, Naylor WP. The effect of tooth preparation form on the fit of Procera copings. Int J Prosthodont 1998;11(6): 580–90.
16. May KB, Russel MM, Razzoog ME, Lang BR. Precision of fit: The Procera AllCeram crown. J Prosthet Dent 1998;80:394–404.
17. McLean JW, VonFraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J 1971;131:107–111.
18. Muller HP. The effect of artificial crown margins at the gingival margin on the periodontal conditions in a group of periodontally supervised patients treated with fixed bridges. J Clin Priodontol 1986;13(2):97–102.
19. Naert I, Van der donic A, Beckers L. Precision of fit and clinical evaluation of all-ceramic full restorations followed between 0.5 and 5 years. J Oral Rehabil 2005; 32:51–7.
20. Odman P, Andersson B. Procera AllCeram crowns followed for 5 to 10 years: a prospective clinical study. Int J Prosthodont 2001;14:504–9.
21. Osman SA, McCabe JF, Walls AW. Film thickness and rheological properties of luting agents for crown cementation. Eur J Prosthodont Restor Dent 2006; 14(1):23–7.
22. Persson M, Andersson M, Bergman B. The accuracy of a high-precision digitiser for CAD/CAM of crowns. J Prosthet Dent 1995;74:223–9.
23. Pröbster L. Klinische Erfahrung mit vollkeramischer Zahnersatz-Ein Rückblick. In: Kappert HF(Hg) Vollkeramik: Werkstoffkunde-Zahntechnik-Klinische Erfahrung. Quintessenz Verlag, Berlin 1996;103–16.
24. Quintas AF, Oliveira F, Bottino MA. Vertical marginal discrepancy of ceramic copings with different ceramic materials, finish lines, and luting agents: an in vitro evaluation. J Prosthet Dent 2004;92(3):250–7.
25. Rosenstiel SF, Gegauff AG. Improving the cementation of complete cast crowns: A comparison of static and dynamic seating methods. J Am Dent Assoc 1988; 117:845–8.
26. Rosenstiel Sf, Land MF, Crispin BJ. Dental luting agents: a review of the current literature. J Prosthet Dent 1998;80:280–301.
27. Silness J. Periodontal conditions in patients treated with dental bridges. The relationship between the location of the crown margin and periodontal condition. J Periodontol Res 1970;5:225–9.
28. Walter MH, Wolf BH, Wolf AE, Boening KW. Six-year clinical performance of all-ceramic crowns with alumina cores. Int J Prosthodont 2006;19(2):162–3.
29. Wilson PR. Low force cementation. J Dent. 1996;24:269–76.
30. Wylie SG, Wilson PR. An investigation into the pressure transmitted to the pulp chamber on crown cementation: a laboratory study. J Dent Res 1994;73(11): 1684–9.
31. Yu Z, Strutz JM, Kipnis V, White SN. Effect of dynamic loading methods on cement film thickness in vitro. J Prosthodont 1995;4:251–5.
32. Zeng K, Oden A, Rowcliffe D. Evaluation of mechanical properties of dental ceramic core materials in combination with porcelains. Int J Prosthodont 1998; 11:183–9.

Submitted February 2008.
Accepted March 2008.

Corresponding author:

Dr Shriharsha Pilathadka BDS, University Hospital Hradec Králové, Department of Dentistry,
Sokolská 581, 500 05 Hradec Králové, Czech Republic, e-mail: shreeharsha_70@yahoo.co.in