©Operative Dentistry, 2014, **39-3,** E101-E108

Retentiveness of Metal Coping Luted to Teeth of Uremic Patients Undergoing Hemodialysis Using Five Different Luting Cements

MH Ghazy • MM Aboumadina • SH Mahmoud

Clinical Relevance

Dental changes have been reported to the teeth of uremic patients that consequently affect bonding of that tissue to fixed restorations.

SUMMARY

Objectives: This study aimed to assess the retention of metal copings luted to uremic teeth with five different luting agents.

Methods: A total of 35 sound natural molars was collected from uremic patients and randomly assigned into five groups (n=7). The teeth were prepared for metal copings using diamond tips and water coolant. Metal copings with a loop on the occlusal surface were fabricated using base metal alloy (Rexillium III). The copings were luted using Fuji I, glass ionomer (GI); Fuji Plus, resin-modified glass ionomer (RMGI); Panavia F 2.0, resin cement; Rely X Unicem, self-adhesive cement (SA); and Adhesor, zinc phosphate cement (ZPh). All specimens were incubated at 37°C for 24 hours, conditioned in artificial saliva for 7 days, and then thermocycled for 5000 cycles (5°C-55°C). The dislodging force was measured using a universal testing machine at a crosshead speed of 2 mm/min. The mode of failure of the loaded adhesive copings was evaluated. Statistical analyses were performed using one-way analysis of variance and Tukey post hoc test.

Results: GI and SA cements had the highest and the lowest mean retentive strength, respectively (580.90±17.3, 406.6±12.7). There was no significant difference between ZPh, SA, and resin cements. These cements were inferior to GI and RMGI cements ($p<0.05$), which showed statistically similar retentive strengths.

Conclusions: The results of this study support the use of glass ionomer and resin-modified glass ionomer cements for luting of metal copings to uremic teeth with retentive preparations.

*Mohamed H Ghazy, PhD, Faculty of Dentistry, Conservative, Mansoura, Dakahlia, Egypt

Manal M Aboumadina, PhD, Faculty of Dentistry, Conservative, Mansoura, Dakahlia, Egypt

Salah Hasab Mahmoud, PhD, Faculty of Dentistry, Mansoura University, Conservative Dentistry Department, Mansoura, El Dakahlia, Egypt

*Corresponding author: El Gomhoria Street, Mansoura, Dakahlia 33516 Egypt; e-mail: mghazy@mans.edu.eg

DOI: 10.2341/12-523-LR2

INTRODUCTION

The retention of crown restorations has always concerned the dental professional, as it affects the longevity of the indirect restorations. Multiple factors affect the success of indirect restorations, such as preparation design, oral hygiene/microflora, mechanical forces, and restorative materials. However, a key factor to success is the choice of a proper luting agent and the cementation procedure. Loss of crown retention was found to be the second leading cause of failure of crowns and fixed partial dentures.[1-3]

Dental luting agents provide a link between the restoration and prepared tooth, bonding them together through some form of surface attachment, which may be mechanical, micromechanical, chemical, or a combination thereof. Zinc phosphate cement has been the most popular luting material for more than 90 years. Excellent clinical performance has been reported for indirect restorations cemented with zinc phosphate cement despite its high solubility and its lack of adhesion.[4,5] Nevertheless, to prevent pain during cementation and to achieve better retention of cast restorations, alternative cements, such as polycarboxylate and glass ionomer cements, were introduced.[6] The adhesion of glass ionomer has been suggested to occur as a result of chemical bonding between negative carboxylate groups in the water-suspended polymer and positive calcium ions in the dental hard tissue.[7] A considerable level of adhesion to both dentin and enamel has been measured *in vitro* for these cements,[8,9] which was also partially confirmed by other clinical studies.[10,11]

With the current advancements of adhesive dentistry, resin cements play an important role for restorative dentistry. These products have several advantages when compared to conventional powder/liquid cements: better retention, minimum solubility in the oral environment, less microleakage, and acceptable biocompatibility.[12,13] Additionally, these materials have the potential of bonding to both substrates (tooth and restoration), favor tooth structure reinforcement, and allow esthetic treatment success.[14,15]

The bond to dentin is obtained by surface pretreatment with acid, followed by application of an adhesive system containing hydrophilic and hydrophobic components.[16] These steps either remove or modify the smear layer and demineralize the dental surface to expose a collagen layer for resin monomer infiltration, consequently forming the hybrid layer.[17]

Self-adhesive resin cements were recently launched into the dental market aiming to simplify the clinical steps and diminish the sensitivity of the previous multiple step technique.[18] The material is directly applied onto tooth surface, without any pretreatment.

The smear layer is partially incorporated by the acid monomers that promote micromechanical retention to tooth structure; chemical retention may occur by the reaction between acid monomers and hydroxyapatite present in tooth hard tissues.[19] Several *in vitro* studies have assessed the impact of luting agents on casting retention.[18-23] These retention tests, which typically were performed by removing a standardized casting from a stylized crown preparation with direct tensile loading, focused on the effects of the type of cement,[23-25] type of metal,[24,25] preparation taper,[20,26] preparation height,[20] surface roughness,[21] and application of dentinal desensitizing agents.[23] The studies related to crown retention and luting cement type reported that adhesive resins had consistently greater retention than zinc phosphate.[18,23,24]

Chronic renal failure (CRF) is defined as a progressive decline in renal function associated with a reduced glomerular filtration rate as measured clinically by the creatinine clearance rate. The interaction between oral health, CRF, and renal replacement therapy has been the subject of many studies during the last 10 years. This scientific interest refers directly to the rising number of end-stage renal failure (ESRF) patients and renal transplanted patients worldwide.[27,28] In the last three to four decades, improvements in dialysis and transplantation have reduced morbidity and mortality among patients with ESRF. As survival improves, more attention must be focused on other areas, such as dental health, which appears to be yet another area where attention has been lacking.[29]

Dental changes including enamel hypoplasia of the primary and permanent teeth with or without brown discoloration and narrowing or calcification of the pulp chamber of teeth of adults with CRF[30] have been reported. In addition, characteristic changes analogous to those seen in bone were detected in dentin of erupted teeth in patients with CRF.[31] Mahmoud and others[32] investigated the influence of uremia on the shear bond strength of resin composite to enamel and dentin substrates with assessment of the micromorphological pattern of etched enamel and dentin surfaces using atomic force microscopy. They reported that uremia adversely affects bonding of resin composite to enamel and dentin and confers

an altered micromorphological etching pattern. A recently published *in vitro* study investigated the effect of phosphoric acid concentration and etching duration on surface roughness of enamel and dentin substrates of uremic patients receiving hemodialysis supported the use of 42% phosphoric acid for etching uremic hard tooth tissues for 60 seconds.[33]

Considering the preceding information and because the success of modern luting cements is greatly dependent on the quality and the performance of their bonds to dental substrates,[16,17] deteriorated or weak bonding of these materials to tooth tissues of uremic patients could be expected. This hypothesis has not been hitherto confirmed or even dismissed in spite of the recent improvements in the chemistry of adhesive systems that have succeeded to a great extent in offsetting the difficulties associated with bonding to different tooth tissues.[34] Accordingly, the aim of this laboratory study was to evaluate and compare the retentive strength of metal copings luted to teeth of uremic patients undergoing hemodialysis using a glass ionomer cement, resin-modified glass ionomer cement, resin cement, and a self-adhesive resin cement with that luted with a zinc phosphate cement.

METHODS AND MATERIALS

Thirty-five sound natural mandibular molars of nearly similar size and shape extracted for periodontal reasons were collected from uremic patients under maintenance hemodialysis. The buccolingual and mesiodistal widths of the selected molars were measured in millimeters allowing a maximum deviation of 10% from the determined mean. The teeth were obtained according to a protocol approved by our Institutional Committee for Ethics of Research. Uremic patients were seeking help for their dental pain at the Outpatient Dental Clinic, Faculty of Dentistry, Mansoura University. They had been referred from the Outpatient Clinic of Mansoura Urology and Nephrology Center. The patients were under regular maintenance hemodialysis treatment using a biocompatible membrane dialyzed with a volumetric machine using bicarbonate dialysate three times weekly for 4 hours each time (12 h/wk). The average length of time that the patients had been receiving hemodialysis was 5.6 years. No patient had decompansated organs other than the kidney. They had serum creatinine above 7 mg/dl and a creatinine clearance rate 10 ml/min; 13 patients were normotensive, and 22 had controlled hypertension. All collected teeth were subjected to thorough scaling (Varios 550, NSK Nakanishi, Kanuma, Japan) to get rid of both hard and soft deposits. All teeth were kept in 1% thymol solution at room temperature for 2 weeks. The teeth had their roots embedded in a cylindrical PVC ring (1.4×2.5 cm) using a self-cure acrylic resin (Duracrol, Sofa-Dental, Prague, Czech Republic) up to 1 mm below the cemento-enamel junction.

Teeth Preparation

All teeth were prepared in a standardized manner using number 837.012 diamond tips (Edenta GmbH, Lustenau, Austria) loaded in an industrial lathe cutting machine (BV series bench lathe, Bengbu, China) aiming to get tooth cylinders having their occlusal plane perpendicular to the long axis of the tooth, 10° axial taper, 7 mm in diameter, and 4 mm high. All of the preparations were made by one experienced operator throughout the study. A polyvinyl siloxane impression (Virtual, Ivoclar Vivadent, Schaan, Liechtenstein) was taken for each prepared tooth and poured with type 4 improved stone (GC, Fuji Rock, Leuven, Belgium) to obtain stone dies.

Construction of Metal Copings

The resultant dies were covered with two coats of die spacer (Yeti Dental, Engen, Germany) 1 mm above the cervical finish line to ensure good marginal adaptation. The dies were lubricated (Die lube, Dentaurum, Ispringen, Germany) and then used to fabricate indirect wax patterns (Plastodent G, DeguDent, GmbH, Hanau-Wolfgang, Germany) using a specially designed split stainless-steel counter die. A wax loop was fabricated and centrally attached to the occlusal surface of the wax pattern parallel to the long axis of the prepared teeth for performing the dislodgment test.

The wax patterns were invested in a phosphate-bonded investment (Ceravest Quick, GC, Tokyo, Japan) and cast in a base metal alloy (Rexillium III, Pentron, Wallingford, CT, USA). After divesting and cleaning with an ultrasonic cleaner and hydrofluoric acid, the inner surface of the castings were inspected under magnification (×4), and surface irregularities were removed with a small round carbide bur. The metal copings were checked for fit using a silicon disclosing medium (Fit Checker, GC Co, Tokyo, Japan), and further potential interferences of castings were evaluated and adjusted if necessary. The intaglio surfaces of all copings were sandblasted using 50-μm aluminum oxide.

Table 1: *Luting Agents Tested*

Product Name	Manufacturer	Lot Number	Type of Luting Agent	Mixing Method and Ratio
Fuji I	GC Co, Tokyo, Japan	0812051	Glass ionomer cement	Automix capsule, 10 s mixing at 4000 rpm
Fuji Plus	GC Co	0905261	Resin-modified glass ionomer cement	Automix capsule, 10 s mixing at 4000 rpm
Panavia F2.0	Kurary Medical Inc, Kurashiki, Japan	00162A, 0023B	Resin-based cement	Hand mix, equal length of base and catalyst
Rely X Unicem	3M ESPE AG, Seefeld, Germany	446227	Self-adhesive resin cement	Aplicap capsule (295 mg per capsule)
Adhesor	SpofaDental a.s., Prague, Czech Republic	2056105	Zinc phosphate cement	Hand mix, 8 g powder with 0.3 cc liquid

Five commercially available luting agents, (Fuji I, Fuji Plus, Panavia F2.0, Rely X Unicem, and Adhesor) cements were evaluated in this study (Table 1). Each cement was mixed according to the manufacturer's instruction and applied to intaglio surface of the copings (n=7). The copings were gently seated on the abutments and held in place under a 5-kg load for 10 minutes using a special device. After initial setting of the cement, the excess cement was removed with an explorer.

Testing

The specimens were stored in a 37°C incubator for 24 hours, immersed in artificial saliva for 7 days (Save-A-Tooth, Phoenix Lazerus, Inc, Pottstown, PA, USA) and thermocycled in distilled water for 5000 cycles between 5±2°C and 55±2°C with a dwell time of 30 seconds and a transfer time of 5 seconds. After the aging process, the dislodging force of the copings was measured using a universal testing machine (Type 500, Lloyd Instruments, London, UK) at a crosshead speed of 2 mm/min (Figure 1). The fitted surfaces of the separated castings were examined visually to determine the mode of cement failure: adhesive, cohesive or a combination. Adhesive failure meant luting cements were totally separated from the casting or tooth surface. Cohesive failure meant failure occurred within the luting agent or tooth structure. Mixed failure meant both cohesive and adhesive. All specimens were fabricated and measured by the same operator.

Figure 1. *Universal testing machine (Type 500, Lloyd Instruments, London, UK).*

Table 2: *Retentive Strength Means (n), Standard Deviation (SD), and Tukey Test (p<0.05)*

Groups	Means[a]	SD	Maximum	Minimum
1: Fuji I	580.90 A	17.35	607.70	562.40
2: Fuji Plus	557.66 A	18.81	576.20	544.10
3: Panavia F2.0	420.39 B	14.30	422.20	391.10
4: Rely X Unicem	410.61 B	12.74	431.20	388.70
5: Adhesor	395.65 B	18.25	420.76	382.13

[a] *Means followed by different letters are statistically different at the 5% significance level.*

Table 3: *Distribution of Mode of Cement Failure in Percentages*

Groups	Cement Totally on Tooth	Cement on Tooth and Casting	Cement Totally on Casting	Dentinal Fracture
1: Fuji I	—	71.4%	—	28.6%
2: Fuji Plus	—	85.7%	—	14.3%
3: Panavia F2.0	—	28.5%	71.5%	—
4: Rely X Unicem	—	14.2%	85.8%	—
5: Adhesor	—	85.7%	14.3%	—

Statistical Analysis

The statistical package for Social Science Version 19 (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis. Retentive force data was analyzed by one-way analysis of variance (ANOVA) and Tukey test with the level of significance set at 5% ($p<0.05$).

RESULTS

ANOVA showed statistically significant differences among the experimental groups, and Tukey test identified the differences ($p<0.05$). Groups 1 and 2 exhibited the highest retentive strength means, respectively, while the lowest mean retentive strength was exhibited by group 4 (Table 2). Tukey test revealed no significant difference between groups 1 and 2. Also, no significant differences were detected among groups 3, 4, and 5 ($p>0.05$). The distribution of the cement mode failure is given in Table 3. Uncommon horizontal fracture of coronal dentin occurred in 28.6% specimens cemented with Fuji I and 14.3% of specimens cemented with Fuji Plus.

DISCUSSION

The permanent cementation of an indirect restoration is a critical step in the overall treatment procedure. If the cement does not live up to its promise, in the worst case a new restoration has to be made. This is time consuming and annoying for dentists as well as for patients. Dentin is a more heterogeneous and physiologically dynamic substrate than enamel. Among other variables, this explains why bonding to dentin is still a challenge despite the improvements in dental adhesive technology and advances in bonding knowledge.[35,36] The literature contains reports[31,37,38] that uremia produced micromorphological changes of dentin and altered etching pattern with reduced surface roughness, which negatively influenced the bonding of resin composite to dental tissues.[32]

Retention is considered an important requirement in the fixation of prosthetic crowns. Clinically, a crown would hardly undergo such great tensile efforts as those applied in this study, but the tested experimental conditions serve as parameters to evaluate behaviors of the luting materials used with uremic dentin substrate. The results of the present study may be explained by the bonding efficacy of the luting agents. Although other factors may influence crown retention, the preparations were standardized (cervical diameter, taper, roughness, and piece fit), thus eliminating or minimizing the interference of these variables on the results.

Concerning the luting agents, the results showed greater retention (Table 2) for the glass ionomer cement (Fuji I) when compared to the zinc phosphate cement (Adhesor), probably due to the chemical diffusion–based adhesion to dentin, improving the retention compared to conventional cements.[39] Moreover, better mechanical properties of glass ionomer cement in relation to zinc phosphate cement also influence their tensile, compressive, and shearing strengths. The lower tensile strength of the zinc phosphate cement may be related to its composition, which makes this material friable and less resistant to tensile forces.[40] Zinc phosphate cement does not have chemical adhesion to any dental substrate, acting only as a luting agent by mechanical or frictional retention. Thus, the height, taper, and area of the preparation are important aspects for its success as a luting material.[40,41] Therefore, in healthy individuals and situations where preparation retention is deficient, such as a short clinical crown and accentuated taper of the preparation, the choice for a luting agent lies with resin cement, leading to a more favorable clinical prognosis.[42]

The retention values obtained in this study by resin cement (Panavia F2.0) and self-adhesive resin (Rely X Unicem) luting agents were lower than those obtained by glass ionomer and resin-modified glass

ionomer luting agents. The inferior retention obtained by these luting agents in the current study could be explained by the impaired adhesion of these cements to uremic dentin substrate. Panavia F2.0 adhered to tooth structure chemically and mechanically. Bonding to dentin may be linked to a form of *in situ* tissue changes, producing a collagen scaffold by acid etching that is infiltrated and stabilized by resin.[43] Since etching appears to be essential for the dentin components in order to form a resin-reinforced hybrid structure, it is important to have sufficient demineralization to allow adhesive penetration. The formed hybrid layer bonds chemically with the resin cement.[44] On the other hand, the unique self-adhesive resin cement Rely X Unicem has made the use of strong resin cement very easy and predictable. This cement is essentially a filled, self-etching primer that provides the physical properties of resin cement.[45] An important factor that determines the technique sensitivity of adhesive systems is individual and locational variation in structural characteristics and mechanical properties of dentin with regard to their high impact on dentin bonding.[46] It was reported that uremia had a deleterious effect on the nature of dentin substrate and reflected negatively on the bonding mechanism of resin-based materials.[30,32] Dentin is a dynamic substrate subject to continuous physiologic and pathologic changes in composition and microstructure. A comparative ultrastructural (scanning electron microscopic) analysis of dentin in patients suffering from chronic renal failure and in patients undergoing chronic hemodialysis revealed a wide spectrum of changes, ranging from mild disturbance with increasing tubule irregularity and focal obliteration of tubule lumens to widespread formation of dysplastic dentin exhibiting numerous mineralized, largely atubular globules with only occasional large, irregular tubules.[38] Daley and others[47] suggested that characteristic changes analogous to those in bone occur in dentin of erupted teeth with ESRF. Wysocki and others[31] carried out morphometric studies on teeth extracted from normal human individuals and compared them with those extracted from patients suffering from CRF; their findings revealed that the predentin in patient suffering from CRF was significantly thicker than normal. Galili and others[48] found narrowing of dental pulp of patients with ESRF and transplanted patients compared to healthy individuals. All of these morphologic and structural transformations of dentin induced by ESRF resulted in a dentinal substrate that is less receptive to adhesive treatment than is normal dentin.

Recently, Mahmoud and others[33] supported the use of 42% phosphoric acid for the etching of uremic hard tooth tissues for 60 seconds. The lower performance of the resin cement and self-adhesive resin cement in comparison to both the glass ionomer and the resin-modified glass ionomer cement can be attributed to the lack of the effect of a surface-conditioning procedure before luting and hybrid layer formation. Thus, the authors recommended that resin cement or self-adhesive resin cements be used in combination with extensive surface-conditioning agents to obtain the best results. In the same context, it should be noted that the lowest retentive values recorded for resin cement and self-adhesive resin cements were still higher than the retentive values obtained with zinc phosphate cement.

The mode of cement failure distribution revealed that fracture occurred at both the cement-metal and the cement-tooth interfaces for copings luted with the zinc phosphate. In no situation was cement observed to completely remain on the prepared tooth. However, cement was completely retained on the casting for 71.5% and 85.8% of copings luted with adhesive resin cement and self-etch adhesive cement, respectively. The chemical pretreatment of polyacrylic acid to tooth structure appeared to enhance a superior bond of glass ionomer and resin-modified glass ionomer cement to tooth structure. On the other hand, in copings luted with the resin cement and self-adhesive resin cement, debonded cement was observed to be retained totally on the metal surface for the majority of the specimens. This shows the inadequate bond of resin cement and self-adhesive resin to the dentinal surface, most likely resulting from the dentinal micromorphological and ultrastructural changes of dentin due to uremia. These changes lead to lack of the effect of conditioner and primer, causing the weak link of the cemented coping assembly to occur at the cement-tooth interface during tensile debonding. Cohesive dentin fracture was observed for 28.6% of copings cemented with the glass ionomer and 14.3% of copings cemented with resin-modified glass ionomer cement. These results confirm the highest retentive values recorded for these cements. These findings were attributed to the fact that dentin of uremic teeth is a totally different substrate compared to normal or even sclerotic dentin. The literature reported that different ultramorphological and structural changes occurred in dentin as a result of uremic syndrome and secondary hyperparathyroidism, making this tissue different than normal.

In this study, the author deals with uremic dentin, a unique substructure, and evaluated the retentive strengths of five different luting cements on base metal alloy copings. Although glass ionomer cement and resin-modified glass ionomer cement showed higher retentive strengths, all tested cements provided retentive strengths exceeding clinically expected debonding forces.[22] Thus, it can be concluded that all five test cements can be used satisfactorily when they are prepared according to the manufacturers' recommendations. The use of glass ionomer and resin-modified glass ionomer cements seems to be advantageous with uremic teeth.

CONCLUSIONS

Under the conditions of this study, the following conclusions could be drawn:

1. All of the tested cements can be used to satisfactorily lute to uremic teeth prepared following conventional mechanical principles.
2. Glass ionomer and resin-modified glass ionomer cements seem to be better choices in luting uremic teeth of retentive preparations.
3. Cohesive dentin fracture occurred with glass ionomer and resin-modified glass ionomer cemented copings.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 15 July 2013)

REFERENCES

1. Schwartz NL, Whitsett LD, Berry TG, & Stewart JL (1970) Unserviceable crowns and fixed partial dentures: life-span and causes for loss of serviceability *Journal of the American Dental Association* **81(6)**1395-1401.
2. Walton JN, Gardner FM, & Agar JR (1986) A survey of crown and fixed partial denture failures length of service and reasons for replacement *Journal of Prosthetic Dentistry* **56(4)** 416-421.
3. Smith CT, Gray JJ, & Conkin JE (1999) Effective taper criterion for the full veneer crown preparation in preclinical prosthodontics *International Journal of Prosthodontics* **8(3)** 196- 200.
4. Yamashita J, Takakuda K, Shiozawa I, Nagasawa M, & Miyairi H (2000) Fatigue behavior of the zinc-phosphate cement layer *International Journal of Prosthodontics* **13(4)** 321-326.
5. Creugers NH, Kayser AF, & van't Hof MA (1994) A meta-analysis of durability data on conventional fixed bridges *Community Dentistry and Oral Epidemiology* **22(6)** 448-452.
6. Wilson AD, Crisp S, Lewis BG, & McLean JW (1977) Experimental luting agents based on the glass ionomer cements *Brazilian Dental Journal* **142(4)** 117-122.
7. Beech DR (1972) A spectroscopic study of the interaction between human tooth enamel and polyacrylic acid (polycarboxylate cement) *Archives of Oral Biology* **17(5)** 907-911.
8. Hotz P, McLean JW, Sced I, & Wilson AD (1977) The bonding of glass ionomer cements to metal and tooth substrates *Brazilian Dental Journal* **142(8)** 41-47.
9. Øilo G (1981) Bond strength of new ionomer cements to dentin *Scandinavian Journal of Dental Research* **89(4)** 344-347.
10. Brandau HE, Ziemiecki TL, & Charbeneau GT (1984) Restoration of cervical contours on nonprepared teeth using glass ionomer cement: A 4½-year report *Journal of the American Dental Association* **108(5)** 782-783.
11. Jemt T, Stålblad P, & Øilo G (1986) Adhesion of polycarboxylate-based dental cements to enamel: An in vivo study *Journal of Dental Research* **65(6)** 885-887.
12. Han L, Okamoto A, Fukushima M, & Okiji T (2007) Evaluation of physical properties and surface degradation of self-adhesive resin cements *Dental Materials Journal* **26(6)** 906-914.
13. Pavan S, Santos PH, Berger S, & Bedran-Russo AKB (2010) The effect of dentin pretreatment on the microtensile bond strength of self-adhesive resin cements *Journal of Prosthetic Dentistry* **104(4)** 258-264.
14. Costa CAS, Teixeira HM, Nascimento ABL, & Hebling J (2007) Biocompatibility of resin-based dental materials applied as liners in deep cavities prepared in human teeth *Journal of Biomedical Materials Research Part* **81(1)** 175-184.
15. Gemalmaz D, & Ergin S (2002) Clinical evaluation of all-ceramic crowns *Journal of Prosthetic Dentistry* **87(2)** 189-196.
16. Garcia RN, de Goes MF, & Giannini M (2007) Effect of water storage on bond strength of self-etching adhesives to dentin *Journal of Contemporary Dental Practice* **8(7)** 46-53.
17. Nakabayashi N, & Pashley DH (1998) *Hybridization of Dental Hard Tissues* Quintessence Publishing, Tokyo.
18. Goracci C, Cury AH, Cantoro A, Papacchini F, Tay FR, & Ferrari M (2006) Microtensile bond strength and interfacial properties of self-etching and self-adhesive resin cements used to lute composite onlays under different seating forces *Journal of Adhesive Dentistry* **8(5)** 327-335.
19. De Munck J, Vargas M, Van Landuyt K, Hikita K, Lambrechts P, & Van Meerbeek B (2004) Bonding of an auto-adhesive luting material to enamel and dentin *Dental Materials* **20(10)** 963-971.
20. El-Mowafy OM, Fenton AH, Forrester N, & Milenkovic M (1996) Retention of metal ceramic crowns cemented with resin cements: Effects of preparation taper and height *Journal of Prosthetic Dentistry* **76(5)** 524-529.

21. Ayad MF, Rosenstiel SF, & Salama M (1997) Influence of tooth surface roughness and type of cement on retention of complete cast crowns *Journal of Prosthetic Dentistry* **77(2)** 116-121.

22. Ernst CP, Wenzl N, Stender E, & Willershausen B (1998) Retentive strengths of cast gold crowns using glass ionomer, compomer, or resin cement *Journal of Prosthetic Dentistry* **79(4)** 472-476.

23. Yim NH, Rueggeberg FA, Caughman WF, Gardner FM, & Pashley DH (2000) Effect of 8 dentin desensitizers and cementing agents on retention of full crowns using standardized crown preparations *Journal of Prosthetic Dentistry* **83(4)** 459-465.

24. Marchiori M, Garbin CA, Rigo L, Nunes DB, & Gilapa GM (2010) Influence of preparation height and luting agent type on crown retention in molars *Brazilian Journal of Oral Science* **9(4)** 89-93.

25. Ergin S, & Gemalmaz D (2002) Retentive properties of five different luting cements on base and noble metal copings *Journal of Prosthetic Dentistry* **88(5)** 491-497.

26. Gundler A, Lockowandt P, & Erhardson S (1993) Crown retention and cyclic loading (in vitro) *Scandinavian Journal of Dental Research* **101(4)** 252-256.

27. Rawska, Stokowska W, & Mysliwiec M (2007) The periodontal status of pre-dialysis chronic kidney disease and maintenance dialysis patients *Nephrology Dialysis Transplantation* **22(2)** 457-464.

28. Levin NW (2007) Periodontal diseases—A modifiable source of systemic inflammation for the end-stage renal disease patient on hemodialysis therapy *Nephrology Dialysis Transplantation* **22(2)** 312-315.

29. Akar H, Akar GC, Carrero J, Stenvinkel P, & Lindholm B (2011) Systemic consequences of poor oral health in chronic kidney disease patients *Clinical Journal of the American Society of Nephrology* **6(1)** 218-226.

30. Ganibegovic M (2000) Dental radiographic changes in chronic renal disease *Medicinski Archiv* **54(2)** 115-118.

31. Wysocki GP, Daly TD, Raymond A, & Ulan MD (1983) Predentin changes in patients with chronic renal failure *Oral Surgery, Oral Medicine, and Oral Pathology* **56(2)** 167-173.

32. Mahmoud SH, Sobh AM, Zaher AR, Ghazy MH, & Abel Aziz K (2008) Bonding of resin composite to tooth structures of uremic patients receiving hemodialysis: Shear bond strength and acid etch patterns *Journal Adhesive Dentistry* **10(5)** 335-338.

33. Mahmoud SH, Ahmed, ME, Mahmoud KM, Grawish ME, & Zaher AR (2012) Effects of phosphoric acid concentration and etching duration on enamel and dentin tissues of uremic patients receiving hemodialysis: An AFM study *Journal of Adhesive Dentistry* **14(3)** 215-221.

34. Miyazaki M, Tsubota K, & Onose H (2002) Influence of adhesive application duration on dentin bond strength of single-application bonding systems *Operative Dentistry* **27(3)** 278-283.

35. Pashley DH, Tay FR, Breschi L, Tjaderhane L, Carvalho RM, & Carrilho M (2011) State of the art etch-and-rinse adhesives *Dental Materials* **27(1)** 1-16.

36. Perdigao J (2010) Dentin bonding—Variables related to the clinical situation and the substrate treatment. *Dental Materials* **26(1)** 24-37.

37. Carl W (1987) Chronic renal failure and hyperparathyroidism: Dental manifestations and management *Compendium of Continuing Dental Education* **8(9)** 697-704.

38. Clark DB, & Wysocki GP (1988) Dentin in chronic renal failure: An ultrastructural study *Journal of Oral Pathology* **17(2)** 60-69.

39. Hosoya Y, & Garcia-Godoy F (1998) Bonding mechanism of Ketac molar aplicap and Fuji IX GP to enamel and dentin *American Journal of Dentistry* **11(5)** 235-239.

40. Fonseca RG, Santos Cruz CA, Adabo GL, & Vaz LG (2004) Comparison of the tensile bond strengths of cast metal crowns luted with resin cements *Journal of Oral Rehabilitation* **31(11)** 1080-1084.

41. Abbo B, Razzoog ME, Vivas J, & Sierraalta M (2008) Resistance to dislodgment of zirconia copings cemented onto titanium abutments of different heights *Journal of Prosthetic Dentistry* **99(1)** 25-34.

42. Diaz-Arnold AM, Vargas MA, & Haselton DR (1999) Current status of luting agents for fixed prosthodontics *Journal of Prosthetic Dentistry* **81(2)** 135-141.

43. Abou Madina M, & Mahmoud S (2007) Uremic dentin: Microtensile bond strength of different adhesive resin cements and ultra morphological observation of resin/dentin interface *Egyptian Dental Journal* **53(2)** 1095-1104.

44. Zidan O, & Ferguson GC (2003) The retention of complete crowns prepared with three different tapers and luted with four different cements *Journal of Prosthetic Dentistry* **89(6)** 565-571.

45. Behr M, Rosentritt M, Wimmer J, Lang R, Kolbeck C, Bürgers R, & Handel G (2009) Self-adhesive resin cement versus zinc phosphate luting material: A prospective clinical trial begun 2003 *Dental Materials* **25(5)** 601-604.

46. Marshall GW Jr, Marshall SJ, Kinney JH, & Balooch M (1997) The dentin substrate: Structure and properties related to bonding *Journal of Dentistry* **25(6)** 441-458.

47. Daley TD, Wysocki GP, & Ulan RA (1982) Dental changes in patients on chronic hemodialysis, Twelfth Biennial ACFD conference on Canadian Dental Research, Halifax Nova Scotia **1(Abstract 13)** 17-21.

48. Galili D, Berger E, & Kaufman E (1991) Pulp narrowing in renal end-stage and transplanted patients *Journal of Endodontics* **17(9)** 442-446.