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Research Article

# A Comparative Evaluation of Cement Application Methods on Marginal Discrepancies and Retention of Cement Retained Implant Restorations: An *In Vitro* Study

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## Abstract

**Purpose of the Study:** The purpose of this study was to evaluate the retention values and marginal adaptation of implant- supported metal crowns using four different cementation techniques.

**Materials and Methodology:** Eighty implant abutment complex (IAC) and metal crowns with defect free and smooth marginal surface were used in the study. Each IAC was composed of a 5.5 mm high titanium abutment screwed onto a 10mm long stainless steel implant analog with 25 Ncm torque according to manufacturer's instructions. The specimens were divided into four groups (groups A-D, twenty specimens per group) according to the cementation technique employed. In Group A, cement was evenly placed over the entire interior marginal surface (IMS) of the crown. In Group B, cement was evenly placed only on the occlusal surface of the crown. In Group C, cement was evenly applied on all the axial walls of interior surface of crown excluding occlusal surface In Group D resin abutment replica technique was used. Zinc phosphate cement (DPI, Harvard) was used for all cementation procedures according to manufacturer's instructions. All specimens were subjected to 1000 thermal cycles between 5˚C and 55˚C with a dwell time of 10 seconds in a thermocycling device. Marginal accuracy was detected after cementation of all specimens by stereomicroscope. The tensile force required to dislodge the copings were determined using a universal testing machine with a cross-head speed of 0.5 mm/ min. Data was collected and statistically analyzed.

**Results:** Highly significant differences in the marginal discrepancies were observed when different cementation techniques were used. Group D (abutment replica) had the highest mean retentive strength while having the least marginal discrepancy when compared to other groups.

**Conclusions:** Based on the results obtained from this study it was concluded that the use of abutment replica technique resulted in the best marginal adaptation retention of cement retained implant prosthesis as compared to other techniques used in the study.

**Keywords:** Implant Crown Cementation; Marginal Discrepancy; Peri Implantitis

## Introduction

Since the inception of dental implants, crestal bone loss has been a subject of major concern. While there are a number of causes for crestal bone loss around dental implants, one iatrogenic cause is retained dental cement [1]. According to the American Academy of Periodontology, excess cement is one of the risk factors for peri-implantitis and peri-implant mucositis [2]. Wilson reported that excess dental cement was associated with signs of peri-implant disease in a majority (81%) of the cases within 4-9 years after implant placement [3].

Hence, the cementation procedure of implant restoration is the weak link around the implant abutment junction. Accurate cementation protocols are often overlooked leading to use of cement in excess than that is required. In clinical practice, this excess cement is very difficult to locate and remove completely [4]. This could lead to plaque accumulation which acts as a nidus for colonization

of microorganisms resulting in peri-implantitis and subsequent crestal bone loss [5-8]. To overcome this problem, there is a need to adopt a cementation protocol which results in minimal or no excess cement.

Cementing techniques with minimal residual cement to achieve a passive fit, with no cement flowing out of the border between the crown and abutment; minimal roughness at the restoration- implant abutment complex junction to alleviate bacterial accumulation; and optimal retention for the restoration are considered favorable. Hence it is important to identify a cementation protocol that reduces excess cement that would cause peri-implantitis leading to implant failure.

Several methods have been proposed for minimizing the amount of cement in the restoration prior to cementation [9,10], during cementation [11], and after cementation [12]. One method for reducing the excess cement is providing a venting hole on the occlusal or lingual aspect of the restoration during cementation; however, more work is needed for creating the orifice and filling it after cementation [13]. Alternatively, a silicone index can also be used as a cementation index for this purpose [14]. Another method of reducing the excess cement before cementation is seating the restoration filled with cement on a practice abutment (analog abutment) extraorally [10,15]. This abutment could be a stock analog or a customized analog made of poly vinyl siloxane (PVS) [15]. After immediate wiping of excess cement, the restoration has to be placed in the mouth [10,15].

Techniques minimizing the amount of cement could control the amount of excess cement, although they might also lead to the formation of marginal gaps [10]. The marginal accuracy of dental restorations is an essential requirement for long-term success [20-23]. Acceptable marginal discrepancy of a restoration has been suggested in the range of 50 - 120 mm [24,25].

Hence, the aim of this *in vitro* study was to a compare and evaluate retention of cement retained implant restorations using universal testing machine and marginal discrepancies with stereomicroscope using different cement application methods.

## Methodology

Eighty implant abutment complex (IAC) and metal crowns with defect free and smooth marginal surface were used in the study. Each IACs was composed of a 5.5mm high titanium abutment screwed onto a 10mm long stainless steel implant analog with 25 Ncm torque according to manufacturer's instructions. Eighty metal crowns with loop on the superior surface was fabricated according to standard laboratory protocols (Figure 1).

**Figure 1:** Implant analog with abutment analog and metal crown with superior loop embedded in acrylic resin.

A 25 µm thick die spacer (Han Dae Chemical Co Ltd) was applied to the surfaces of resin abutment replicas. Four index indentations across the margins of the crown and IACs/resin abutment replicas was marked at approximately equal distances with the surgical scalpel (blade #15) under the stereomicroscope for further measurements.

Before cementation, all the crowns was cleaned in an ultrasonic bath with distilled water for 10 minutes, wiped with alcohol and inspected under stereomicroscope. Each crown set on corresponding IAC embedded individually in acrylic resin block and each area containing indentation was examined using stereomicroscope with 10× objective lens. Zinc phosphate cement (DPI, Harvard) was used for all cementation procedures according to manufacturer's instructions. For each specimen, the cement was mixed on a mixing pad according to manufacturer's instructions. The specimens were divided into four groups (groups A-D, twenty specimens per group) according to the cementation technique employed.

- In Group A, cement was evenly placed over the entire interior marginal surface (IMS) of the crown by using explorer, followed by seating the crown along the long axis of the IAC with manual compression for 10 seconds. Excess cement was removed with an explorer.

- In Group B, cement was evenly placed only on the occlusal surface of the crown by using explorer, followed by seating the crown along the long axis of the IAC with manual compression and loading.
- In Group C, cement was evenly applied on all the axial walls of interior surface of crown excluding occlusal surface using explorer, followed by seating the crown along the long axis of the IAC with manual compression and loading.
- In Group D, Die spacer was applied into the intaglio surface of the crown restoration according to the manufacturer's recommendations (Han Dae Chemical Co Ltd). The crown was completely filled with a bis-acrylic temporary restorative material (pattern resin: GC Dental Products Corp) and a retention pin with a smaller diameter tip was placed into the uncured material to form a handle and retention pin was secured until the bis-acrylic material was cured (Figure 2). The crown was removed and checked for any discrepancies between the implant abutment and the bis-acrylic abutment. There were no voids on the duplicate abutment, and the finish line was duplicated accurately. The intaglio surface of the crown restoration was cleaned with air and checked for any residual die spacer.


**Figure 2:** GC pattern resin.

Approximately twice the amount of cement used in group A was evenly placed on the entire IMS of the crown. Resin abutment replica was pressed on the crown along its long axis, and the excess cement was immediately wiped off with cotton gauze. The resin abutment replica was then removed along the long axis of the crown, followed by seating of the crown, manual compression and loading (Figure 3).

**Figure 3:** Abutment replica.

So,

Group A (entire interior marginal surface) = 20; n= 80

Group B (only occlusal surface) =20

Group C (all axial wall) = 20

Group D (Abutment Replica) = 20.

## Testing of specimens

Ten hours after the cementation, all the specimens were subjected to 1000 thermocycles between 5°C and 55° C with a 30 second dwell time in each water bath. The marginal area of each specimen was examined using stereomicroscope and then all the measurements were conducted.

To assess the retention of crowns after cementation, pull out test was done. The uniaxial retention force test applies low-speed removal forces on the crown and implant abutment complex (IAC). The tensile strength was measured by pulling the crown from IAC with the Universal Testing Machine (Mecmisin) at the Indian Institute of Science Bangalore at a crosshead speed of 0.5 mm/min.

## Statistical analysis of data

The data collected was entered in excel sheet and analyzed using IBM SPSS Statistics, Version 22(Armonk, NY: IBM Corp). Descriptive data was presented in the form of mean and standard deviation. The tensile strength between the four groups was compared using One Way ANOVA followed by Post hoc Tuckey test. P value < 0.05 will be considered as statistically significant.

## Results

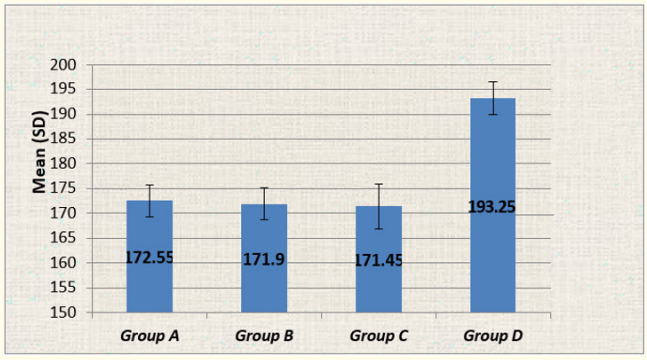
### Retention

This study evaluated and compared the effect of different cementation techniques on retention of cement retained implant prosthesis using zinc phosphate cement. The results revealed that there was a statistically significant difference between the different cementation techniques with regard to retention (Table 1). All values obtained were highly statistically significant with $p < 0.001$. The mean of retention values for Group D (abutment replica technique) was the highest, followed by Group A (entire interior marginal surface), Group B (only occlusal surface) and Group C (on all the axial walls) as interpretated by ANOVA test (Graph 1).

| Group | N | Mean | Std. Deviation | F value | P value |
|---|---|---|---|---|---|
| Group A | 20 | 172.55 | 3.203 | 173.930 | <0.001** |
| Group B | 20 | 171.90 | 3.194 | | |
| Group C | 20 | 171.45 | 4.524 | | |
| Group D | 20 | 193.25 | 3.354 | | |
| Total | 80 | 177.29 | 9.935 | | |

**Table 1:** Comparison of the tensile strength among all the groups using ANOVA test.

(p< 0.05 - Significant*, p < 0.001 - Highly significant**).




**Graph 1:** Comparison of the tensile strength in among all the groups using ANOVA test.

Post Hoc tests showed the mean difference of retention with different cementation techniques was highly significant. Comparison of the tensile strength among all the groups using Tukey's post hoc analysis was highly significant with $p < 0.001$ (Table 2).

| | Group A | Group B | Group C | Group D |
|---|---|---|---|---|
| Group A | - | 0.941 | 0.771 | <0.001** |
| Group B | 0.941 | - | 0.979 | <0.001** |
| Group C | 0.771 | 0.979 | - | <0.001** |
| Group D | <0.001** | <0.001** | <0.001** | - |

**Table 2:** Comparison of the tensile strength among all the groups using Tukey's post hoc analysis.

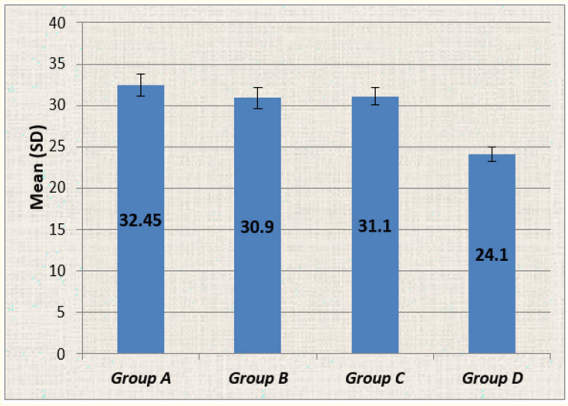
### Marginal discrepancy

This study evaluated and compared the effect of different cementation techniques on marginal discrepancy of cement retained implant prosthesis using zinc phosphate cement. There were statistically significant differences between the different cementation techniques with regard to marginal discrepancy (Table 3). The mean of marginal discrepancy for Group D was the lowest, followed by Group B, Group C and Group A (Graph 2).

| Group | N | Mean | Std. Deviation | F value | P value |
|---|---|---|---|---|---|
| Group A | 20 | 32.45 | 1.356 | 213.607 | <0.001** |
| Group B | 20 | 30.90 | 1.252 | | |
| Group C | 20 | 31.10 | 1.071 | | |
| Group D | 20 | 24.10 | 0.852 | | |
| Total | 80 | 29.64 | 3.461 | | |

**Table 3:** Comparison of the marginal discrepancy among all the groups using ANOVA test.

(p < 0.05 - Significant*, p < 0.001 - Highly significant**).




**Graph 2:** Comparison of the marginal discrepancy among all the groups using ANOVA test.

Post Hoc tests showed the mean difference of marginal discrepancy with different cementation techniques was highly significant. Comparison of the marginal discrepancy among all the groups using Tukey's post hoc analysis was highly significant with $p < 0.001$ (Table 4).

| | Group A | Group B | Group C | Group D |
|---|---|---|---|---|
| Group A | - | <0.001** | 0.002* | <0.001** |
| Group B | <0.001** | - | 0.946 | <0.001** |
| Group C | 0.002* | 0.946 | - | <0.001** |
| Group D | <0.001** | <0.001** | <0.001** | - |

**Table 4:** Comparison of the marginal discrepancy among all the groups using Tukey's post hoc analysis.

## Discussion

One of the critical factors for success of implant-supported restorations is the connection integrity of prosthetic superstructure to the implant [26]. This integrity is provided by cement as means of implant-prosthesis retention.

But unfortunately there is no guideline for the appropriate amount of cement needed for cementation of restorations. Using too little cement could lead to leakage and inadequate retention, while using too much cement could cause other problems, such as alteration in occlusal position of the restoration (incomplete seating of the restoration), possible harm to peri- implant tissues, and more difficulty in cleaning the excess cement [9,27-29].

The amount of excess cement depends on the technique of cementation and also the type of cement, cement viscosity, sub gingival margin placement, chemical composition of cement, diameter of implant [30]. Other contributing factors include forces during placement, margin integrity, ability to remove unset cement, abutment material, texture, and shape. Visual and tactile method of locating and eliminating excess cement is clinically a challenging task [31,32]. Wadhwani., *et al*. [33] concluded that zinc containing cements can be easily detected on radiographs even at 1mm thickness while glass ionomer cement and resin cement are not well demarcated at 1mm thickness and minimum 2mm of thickness is needed for their detection radiographically.

Zinc phosphate exhibits sufficient compressive and tensile strength, has a longer working time and excess cement can be easily removed without scratching the implant surface [16]. The luting property of zinc phosphate cement is achieved mainly from mechanical interlocking [17-19]. Therefore the cement of choice used in this study is zinc phosphate cement.

Thermocycling simulates thermal changes in the oral cavity [34]. It has been used for evaluating retentiveness of luting agents for metal components [35], bond strengths of luting agents to an implant system [36] and microleakage associated with luting agents [36]. GaRey., *et al*. [37] found that thermocycling has minimal effect on retentiveness of resin cements. This finding may be attributed to the low solubility of resin cements compared with other luting agents [38]. Zinc phosphate cement used in this study has high solubility, therefore to mimic similar solubility, specimens were subjected to 1000 thermocycles between 5°C and 55°C with a 30 second dwell time in each water bath.

The present study also measured the vertical marginal discrepancy, which was described by Holmes., *et al.* [39] as the "vertical marginal misfit measured parallel to the path of draw of the casting". Measurement data was obtained by positioning the specimens under the microscope so that the marginal area of the implant-restoration junction was viewed from a directly perpendicular perspective. Other investigators have also used this methodology to easily and accurately report marginal misfit [40,41]. This allows for measurement of the marginal discrepancy in a nondestructive format that allows multiple readings on specimens throughout the prosthetic crown fabrication process.

Since marginal adaptation and retention are among the main criteria for success of a restoration, they need to be thoroughly investigated. In this *in vitro* study, cement failure load and marginal adaptation were evaluated on single- unit castings cemented to implant abutments. Zinc phosphate cement with four different cementation techniques was tested using thermal cycling to simulate the intraoral environment. In this study, it was found that there were differences in retentiveness and marginal adaptation among the metal copings cemented with different cementation techniques. The Group D i.e. abutment replica group (AR) had the highest retention and least marginal discrepancy (Figure 1 and 2, table 1 and 3). In a study conducted by Tian Liang., *et al.* [42], they compared the retentive strength and linear roughness and marginal discrepancy with different luting cementation techniques with resin cement as luting agent. The results were in accordance with

this study. This study also concluded that cementing technique affects retention and marginal discrepancy in cement retained implant supported prosthesis.

Results of this study showed that abutment replica technique showed highest tensile strength compared to other techniques for implant retained crowns (Figure 1, table 1 and 2). The results of this study are in agreement with another study conducted by Tiang Liang., *et al.* [42] where they have also compared retention of cement retained implant prosthesis by using three different cementation techniques.

Another factor is the choice of abutment replica. Several methods are available for fabricating these replicas. They can either be fabricated along with the other implant elements by the manufacturers (practice abutment) or duplicated with resin or fast-setting materials (resin abutment replica) [10,15,43]. The former method allows a more accurate configuration of the actual abutment to facilitate adequate spreading, while the latter method is less time consuming and more cost efficient; even if a deviation exists, it can be adjusted by the fluidity of the cement.

Conventionally, a die spacer is applied on die surfaces during the fabrication of restorations to reserve space for cement, thus facilitating a passive fit for the fabricated crown [44]. Few clinical studies involve the use of a resin abutment replica during cementation [45]. More studies on the clinical applications of these cementing techniques are needed to further verify the findings in this study.

One limitation of this study was the use of a pure tensile test. The clinical stresses may not be represented by purely tensile test where other non-axial forces may contribute to crown decementation [46]. However, the pure tensile testing was used because it represents the worst case clinical scenario, and has been adopted in other studies and could allow comparison of our results with previous investigations.

As it was an *in vitro* study, it can be concluded that these findings represent a best-case scenario, as the seating of the finished prosthesis was not inhibited by the soft tissues often present in intimate approximation with implants in situ. Clinical experience dictates that as the depth of the implant restoration interface increases, the likelihood of trapping gingival tissues and incomplete seating of the prosthesis increases greatly. Hence further clinical studies are recommended to evaluate the effect of different cementation techniques on marginal discrepancy and retention of cement retained implant supported prosthesis.


**Figure 4:** Zinc phosphate cement.

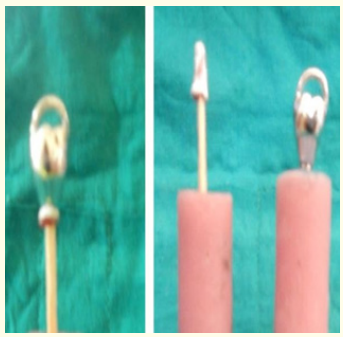


**Figure 5:** Cementation using abutment replica.

**Figure 6:** Thermocycling unit.

**Figure 7:** Stereomicroscope.


**Figure 8:** Universal testing machine.

## Conclusion

Within the limitations of the present study, the following conclusions could be drawn:

- Vertical marginal gap values of all tested cements were within the clinically acceptable range of less than 120µm.
- The use of abutment replica technique resulted in the best marginal adaptation as compared to other techniques used in the study.
- The use of abutment replica technique resulted in the best retention of cement retained implant prosthesis as compared to other techniques used in the study.

## Bibliography

1. Present S and Levine RA. "Techniques to control or avoid cement around implant-retained restorations". *Compendium of Continuing Education in Dentististry* 34 (2013): 432-437.
2. "Academy report: Peri-implant mucositis and peri-implantitis: a current understanding of their diagnoses and clinical implications". *Journal of Periodontology* 84.4 (2013): 436-443.
3. Wilson TG Jr. "The positive relationship between excess cement and peri-implant disease: A prospective clinical endoscopic study". *Journal of Periodontology* 80 (2009): 1388-1392.
4. Wadhwani C and Piñeyro A. "Implant cementation, step by step guidance and advice to help you acquire confident technique". *Nobel Biocare News* 13 (2011): 11.
5. Chee WW., *et al*. "Retrievable cemented implant restorations". *Journal of Prosthodontics* 7 (1998): 120-125.
6. Chee W and Jivraj S. "Screw versus cemented implant supported restorations". *British Dental Journal* 201 (2006): 501-507.
7. Chee W., *et al*. "Cemented versus screw-retained implant prostheses: Which is better?" *International Journal of Oral and Maxillofacial Implants* 14 (1999): 137-141.
8. Hebel KS and Gajjar RC. "Cement-retained versus screw-retained implant restorations: Achieving optimal occlusion and esthetics in implant dentistry". *Journal of Prosthetic Dentistry* 77 (1997): 28-35.
9. Wolfart M., *et al*. "Retention forces and seating discrepancies of implant- retained castings after cementation". *International Journal of Oral and Maxillofacial Implants* 21 (2006): 519-525.
10. Dumbrigue HB., *et al*. "Techniques to minimize excess luting agent in cement-retained implant restorations". *Journal of Prosthetic Dentistry* 87 (2002): 112-114.
11. Sharifi N., *et al*. "Alternative restorative techniques of the CeraOne single- tooth abutment. A technical note". *International Journal of Oral and Maxillofacial Implants* 9 (1994): 235-238.
12. Agar JR., *et al*. "Cement removal from restorations luted to titanium abutments with simulated subgingival margins". *Journal of Prosthetic Dentistry* 78 (1997): 43-47.

13. Schwedhelm ER., *et al*. "A crown venting technique for the cementation of implant-supported crowns". *Journal of Prosthetic Dentistry* 89 (2003): 89-90.

14. Chee WW., *et al*. "Evaluation of the amount of excess cement around the margins of cement retained dental implant restorations: the effect of the cement application method". *Journal of Prosthetic Dentistry* 109 (2013): 216-221

15. Wadhwani C and Pi˜neyro A. "Technique for controlling the cement for an implant crown". *Journal of Prosthetic Dentistry* 102 (2009): 57-58.

16. Schiessl C., *et al*. "Factors determining the retentiveness of luting agents used with metal- and ceramic-based implant components". *Clinical Oral Investigation* 17 (2013): 1179-1190.

17. Augstin-Panadero R and Fons-Font. "A Zirconia versus metal: A preliminary comparative analysis of ceramic veneer behavior". *International Journal of Prosthodontics* 25 (2012): 294-300.

18. Clayton GH., *et al*. "The effect of luting agents on the retention and marginal adaptation of the ceraOne implant system". *International Journal of Oral and Maxillofacial Implants* 12 (1997): 660-665.

19. Li TH., *et al*. "Retention and marginal adaptation of luting agents on dental implant-supported prostheses". *Taiwan Journal of Oral and Maxillofacial Surgery* 25 (2014): 88-99.

20. Pan YH and Lin CK. "The effect of luting agents on the retention of dental implant-supported crowns". *Chang Gung Medical Journal* 28 (2005): 403-410.

21. Baig MR., *et al*. "Evaluation of the marginal fit of a zirconia ceramic computer-aided machined (CAM) crown system". *Journal of Prosthetic Dentistry* 104 (2010): 216-227.

22. Boening KW., *et al*. "Clinical fit of Procera AllCeram crowns". *Journal of Prosthetic Dentistry* 84 (2000): 419-424.

23. Pjetursson BE., *et al*. "A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part I: Single crowns". *Clinical Oral Implants Research* 18 (2007): 73-85.

24. Suarez MJ., *et al*. "Comparison of the marginal fit of Procera All Ceram crowns with two finish lines". *International Journal of Prosthodontics* 16 (2003): 229-232.

25. Tan PL., *et al*. "An in vitro comparison of vertical marginal gaps of CAD/CAM titanium and conventional cast restorations". *Journal of Prosthodontics* 17 (2008): 378-383.

26. Breeding LC., *et al*. "Use of luting agents with an implant system: Part". *Journal of Prosthetic Dentistry* 68 (1992): 737-741.

27. Pauletto N., *et al*. "Complications associated with excess cement around crowns on osseointegrated implants: a clinical report". *International Journal of Oral and Maxillofacial Implants* 14 (1999): 865-868.

28. Gapski R., *et al*. "Endosseous implant failure influenced by crown cementation: a clinical case report". *International Journal of Oral and Maxillofacial Implants* 23 (2008): 943-946.

29. Linkevicius T., *et al*. "The influence of margin location on the amount of undetected cement excess after delivery of cement retained implant restorations". *Clinical Oral Implant Research* 22 (2011): 1379-1384.

30. Korsch M., *et al*. "Predictors of excess cement and tissue response to fixed implant-supported dentures after cementation". *Clinical Implant Dentistry and Related Research* 17 (2015): 45-53.

31. Valderhaug J and Heloe LA. "Oral hygiene in a group of supervised patients with fixed prostheses". *Journal of Periodontology* 48 (1977): 221-224.

32. Vindasiute E., *et al*. "Clinical factors influencing removal of the cement excess in implant-supported restorations". *Clinical Implant Dentistry and Related Research* 17 (2015): 771-778.

33. Wadhwani C., *et al*. "Radiographic detection and characteristic patterns of residual excess cement associated 268 Volume 119 Issue 2 with cement-retained implant restorations: a clinical report". *Journal of Prosthetic Dentistry* 107 (2012): 151-157.

34. Gale MS and Darvell BW. "Thermal cycling procedures for laboratory testing of dental restorations". *Journal of Dentistry* 27 (1999): 89-90.

35. Squier RS., *et al*. "Retentiveness of dental cements used with metallic implant components". *International Journal of Oral and Maxillofacial Implants* 16 (2001): 793-798.

36. White SN., *et al*. "Microleakage of new crown and fixed partial denture luting agents". *Journal of Prosthetic Dentistry* 67 (1992): 156-161.

37. GaRey DJ., *et al*. "Effects of thermocycling, load-cycling, and blood contamination on cemented implant abutments". *Journal of Prosthetic Dentistry* 71 (1994): 124-132.

38. Eckert SE and Wollan PC. "Retrospective review of 1170 endosseous implants placed in partially edentulous jaws". *Journal of Prosthetic Dentistry* 79 (1998): 415-421.

39. Holmes JR., *et al*. "Considerations in measurement of marginal fit". *Journal of Prosthetic Dentistry* 62 (1989): 405-407.

40. Sutherland JK., *et al*. "Marginal discrepancy of all-ceramic crowns cemented on implant abutments". *Journal of Prosthodontics* 4 (1995): 173-177.

41. Clayton GH., *et al*. "The effect of luting agents on the retention and marginal adaptation of the CeraOne implant system". *International Journal of Oral and Maxillofacial Implants* 12 (1997): 660-665.

42. Tian L., *et al*. "Comparative in vitro study of cementing techniques for implant supported restorations". *Journal of Prosthetic Dentistry* 116 (2016): 59-66.

43. Gervais MJ and Wilson PR. "A rationale for retrievability of fixed, implantsupported prostheses: a complication-based analysis". *International Journal of Prosthodontics* 20 (2007): 13-24.

44. Carter SM and Wilson PR. "The effects of die-spacing on post-cementation crown elevation and retention". *Australian Dental Journal* 42 (1997): 192-198.

45. Galván G., *et al*. "Cemented implant restoration: A technique for minimizing adverse biologic consequences". *Journal of Prosthetic Dentistry* 114 (2015): 482-485.

46. Kaar D., *et al*. "The effect of fatigue damage on the force required to remove a restoration in a cement-retained implant system". *Journal of Prosthodontics* 15 (2006): 289-294.