Acta Scientific Dental Sciences (ISSN: 2581-4893)
Volume 7 Issue 2 February 2023

Research Article

Effect of Luting Agents and Height of Implant Abutments on the Retentive Properties of Copings - an *In Vitro* Study

Surya Rengasamy[1], K Chandrasekharan Nair[2]* and Jayakar Shetty[3]

[1]Reader, Department of Prosthodontics and Implantology, SRM Kattan Kulathur Dental College and Hospital, Chengalpattu, Tamil Nadu

[2]Professor Emeritus, Department of Prosthodontics, Sri Sankara Dental College, Akathumuri, Thiruvananthapuram, Kerala, India

3Former Professor, Department of Prosthodontics, AECS Maaruti College of Dental Sciences, Bangalore, India

***Corresponding Author:** K Chandrasekharan Nair Professor Emeritus, Department of Prosthodontics, Sri Sankara Dental College, Akathumuri, Thiruvananthapuram, Kerala, India.

DOI: 10.31080/ASDS.2023.07.1560

Received: December 27, 2022
Published: January 09, 2023

Abstract

Objective: 1. To determine the effect of luting agents viz. zinc phosphate cement and non-eugenol cement on the retention of copings, 2. To determine the effect of height of the implant abutments viz. 4mm and 6mm on the retention of copings and 3. To determine the effect of type of copings viz. Zirconia and metal on the retention of copings cemented to implant abutments.

Methodology: TTwo brands of standard titanium implant abutments of 3.75mm diameter and 6 degree taper were used (ADIN, MIS implant systems). The abutments were machined to two different heights viz. 4mm and 6mm. The implant analogs with the abutment were positioned in cylindrical bases. Two types of copings were fabricated viz. metal copings and Zirconia copings. The copings were cemented with zinc phosphate cement (De Trey Zinc) and non-eugenol cement (Provicol). The cemented specimens were stored for 24 hours at 370C. Tensile testing was done using universal testing machine (Instron) at a cross-head speed of 1mm/min. Data was statistically analyzed with factorial ANOVA.

Results: The tensile strength was maximum for 6mm MIS implant abutment when Zirconia coping was cemented with De Trey Zinc cement (556 ± 27.34N). The minimum was seen with 4mm MIS abutment when metal coping was cemented with Provicol cement (60.90 ± 5.72N). There was statistically significant difference between the groups ($p < 0.001$).

Conclusion:

- The two brands of dental implants viz. MIS and ADIN behaved almost in a similar fashion with respect to the variables such as the materials used for preparing the copings, cement used for luting and the height of the abutments.
- Height of the implant abutment and the retention of the copings have a directly proportional relationship.
- While comparing Zirconia and metal copings, the former always exhibited superior retention.
- De Trey Zinc always showed higher mean retention strength when used with metal or Zirconia copings.
- The combination of Zirconia copings, De Trey Zinc luting cement and abutment with 6mm height exhibited the maximum retention strength.
- With 4mm abutments, the luting cement preference that can be recommended is zinc phosphate followed by provisional cement whereas with 6mm abutments, the preferential order is reversed. If the retention values are high, retrieval attempts may challenge the osseointegration.

Keywords: Retention; Tensile Bond Strength; Cement Retained Implant Prosthesis; Height of Abutment; Luting Agents

Introduction

Dental implants have ushered in a new era in dentistry and its predictable success has ignited the imagination of the practicing dentists. Numerous options of treatment could be planned and which in the recent past were considered as not feasible. Success of implant treatment was attributed exclusively to the maintenance of osseointegration during the functional period. Once osseointegration could be optimized with assured and predictable success, the major attention got shifted to the design of abutments. Abutment fixed to the implant fixture through a slender, threaded screw has been a popular design but very often it challenged the success through loosening or fracture. Once the abutment receives a cemented crown, the implant abutment assembly poses a precarious situation of preventing the clinician from undertaking meticulous scrutiny of the implant assembly. It is an alarming situation that the implant remains intact with successful osseointegration and abutment is intact with a perfectly cemented crown but the connecting abutment screw is loose. Removing the crown with an impact force may appear to be a simple solution but it can jeopardize the intactness of the crown, continuity of the abutment screw and eventually the bone-implant contact. Interestingly, the clinician is not aware of the force at which the bone-implant contact fails or the quantity of the impact forces exerted by the crown removers. If the luting cement is not kind to the conventional retrieval processes, the only option left to the clinician is to sacrifice the carefully crafted crown. Two factors are of primary concern: 1. binding capability of the luting cements that retains the implant supported crown should be just optimum 2. abutment morphology, to be precise the height of the implant abutment. A number of studies have been undertaken in the last two decades on the bonding of luting agents, the abutment height and different types of crowns viz. metallic and zirconia [1-11]. The plentiful documented data available based on different luting agents very often confuses the Indian professionals. Hence it was decided to focus on products available in India and popularly used by the Indian dentists and to find out optimum values of retentivity provided by different types of cements used in implant supported crowns and the role of abutment height and hence this *in vitro* evaluation was designed. The following were the objectives of the present study.

- To determine the effect of luting agents on the retention values of implant copings viz. zinc phosphate cement and non-eugenol cement on the retention values of copings
- To determine the effect of height of the implant abutments viz. 4mm and 6mm on the retention values of copings
- To determine the retention values of implant copings made of two different materials viz. Nickel chromium and Zirconia

Methodology

The present study was conducted to determine the effect of luting agents, height of implant abutment and the type of coping on the retentive properties of cement retained implant prosthesis.

Preparation of specimens

Two brands of standard titanium implant abutments of 3.75mm diameter and 6^0 taper were selected (ADIN, MIS implant systems) (Figure 1,2). The abutments were machined to two different heights viz. 4mm and 6mm (Figure 3). Matching implant analogues were also selected. Implant analogues were secured into a cylindrical base (Figure 4) with autopolymerising acrylic resin. The implant analogue with the abutment was positioned in the base using a dental surveyor in order to obtain vertical alignment (Figure 5,6). The occlusal access opening of each abutment was filled with polyvinyl siloxane putty.

Figure 1: MIS Implant analogue and abutment.

Figure 2: ADIN Implant analogue and abutment.

Figure 3: Abutments machined to 4mm and 6mm height.

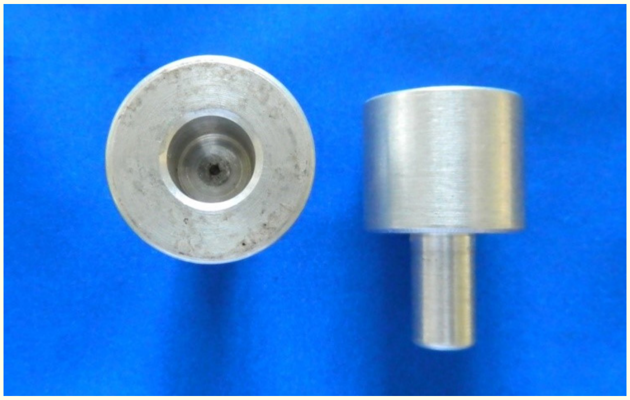

Figure 4: Aluminium base used for fixing the specimen.

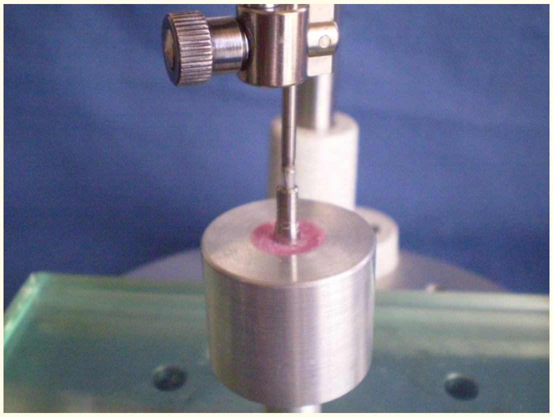

Figure 5: Implant assembly fixed to the base with autopolymerising acrylic resin.

Figure 6: Implant assembly fixed to the bases.

Preparation of copings

A custom tray made in auto polymerizing acrylic resin with 4-mm wax relief was used to make the impression of the abutment with poly vinyl siloxane light body impression material. Metal and Zirconia copings were fabricated. Metal copings were casted in commercially available Nickel chromium alloy. (Figure 7). Zirconia copings were milled in InLab MC XL Sirona machine (Figure 8), Each coping had a 2mm occlusal perforation through which a wire could be passed and held for tensile testing. Each sample was labelled according to the abutment it received.

Cementation of copings

The zirconia and metal copings were cemented to the abutments using two different cements viz. Non eugenol cement (Provi-

Figure 7: Metal copings cemented to the implant assembly.

Figure 8: Zirconia copings cemented to the implant assembly.

col) and Zinc phosphate cement (De Trey Zinc). The cements were applied to the intaglio surfaces of the copings and seated on the abutments with firm finger pressure for 10 seconds followed by a load of 5 kgs applied for 10 minutes (Figure 9). The specimens were then stored in a water bath kept at 37^0 C for 24 hours prior to further testing.

Experimental groups

The specimens were divided into 16 groups (Table 1) based on brand of implant, type of coping, the luting agent and the height of the abutment. Tensile testing for each group was done 10 times so that a total of 160 readings were obtained.

Figure 9: Cemented specimen loaded with a weight of 5kg.

Test of tensile bond strength

The cemented copings were connected to the upper member of the universal testing machine (Figure 10-12) by threading a braided wire through the perforation of the coping. The wire was attached to the upper member of the testing machine and secured tightly in place.

The base containing the implant analog/abutment/coping assembly was connected to the lower member of the testing machine. The upper member of the testing machine was raised manually until initial tension was achieved. The retention of the copings was measured by applying a tensile force sufficient to dislodge the coping from the abutment, using a tensile load, at a crosshead speed of 1 mm/min. The removal force was applied along the long axis of the specimens, and the maximum load required to remove the copings was recorded in Newtons. After each testing period, the cement on the inner surface of the coping and on the abutment was removed. Copings and abutments were placed in an ultrasonic cleaner for 30 minutes and then wiped once with cotton gauze. All the specimens were allowed to air dry and were visually inspected. The testing was done similarly for all the groups.

Sl.no	Code	Implant Brand	Coping material	Luting agent	Height of abutment
1.	MMP4	MIS	Metal	Provicol	4mm
2.	MMP6	MIS	Metal	Provicol	6mm
3.	MMD4	MIS	Metal	DeTrey Zinc	4mm
4.	MMD6	MIS	Metal	DeTrey Zinc	6mm
5.	MZP4	MIS	Zirconia	Provicol	4mm
6.	MZP6	MIS	Zirconia	Provicol	6mm
7.	MZD4	MIS	Zirconia	DeTrey Zinc	4mm
8.	MZD6	MIS	Zirconia	DeTrey Zinc	6mm
9.	AMP4	ADIN	Metal	Provicol	4mm
10.	AMP6	ADIN	Metal	Provicol	6mm
11.	AMD4	ADIN	Metal	DeTrey Zinc	4mm
12.	AMD6	ADIN	Metal	DeTrey Zinc	6mm
13.	AZP4	ADIN	Zirconia	Provicol	4mm
14.	AZP6	ADIN	Zirconia	Provicol	6mm
15.	AZD4	ADIN	Zirconia	DeTrey Zinc	4mm
16.	AZD6	ADIN	Zirconia	DeTrey Zinc	6mm

Table 1: Description of the experimental groups.

Figure 10: Universal testing machine.

Figure 11: Specimen attached to the Universal testing machine with a wire loop.

Figure 12: Dislodgement of the coping on application of tensile load.

Results and statistical Analysis

Results were tabulated and subjected to Factorial ANOVA to detect statistically significant differences. A summary of methodology is given in the flow chart (Figure 13).

Results

In this experiment, four factors influenced the retention strength viz. Brand of implant abutment, Materials used for copings, Luting agents and the different heights of the abutments. The factors and their levels are shown in table 2.

Null hypotheses

- **$H_{0(a)}$:** There is no significant difference between the two types of Brands.
- **$H_{0(b)}$:** There is no significant difference between the two types of Copings
- **$H_{0(c)}$:** There is no significant difference between the two types of Luting Agents
- **$H_{0(d)}$:** There is no significant difference between the two types of Heights
- **$H_{0(e)}$:** The interaction (joint effect) of the different factors is not significant.

Alternate hypotheses

- **$H_{1(a)}$:** There is a significant difference between the two types of Brands.
- **$H_{1(b)}$:** There is a significant difference between the two types of Copings.
- **$H_{1(c)}$:** There is a significant difference between the two types of Luting Agents.
- **$H_{1(d)}$:** There is a significant difference between the two types of Heights.
- **$H_{1(e)}$:** The interaction (joint effect) of various factors is significant.

Level of significance

$\alpha = 0.05$.

Decision criterion

The p-values were compared to find out the level of significance. If $P < 0.05$, the null hypothesis was rejected and accepted the alternate hypothesis. If $P > 0.05$, the null hypothesis was accepted.

Statistical technique used

Factorial ANOVA

Higher mean retention strength was recorded in ADIN compared to MIS but the difference between them was not statistically significant ($P > 0.05$). When copings were compared, higher mean retention strength was recorded in Zirconia copings when compared to Metal copings and the difference between them was found to be statistically significant ($P < 0.001$). Between the two luting agents, higher retention strength was recorded in De Trey Zinc in comparison to Provicol and the difference between them was found to be statistically significant ($P < 0.001$). Higher retention strength was recorded with 6mm height of the abutments when compared to 4mm height and the difference between them was found to be statistically significant ($P < 0.001$). Except for the joint effect of brand/coping/height, all other interactions provided statistically significant results. (Table 3,4). Luting agents was the most important factor that provided superior retention followed by height of the abutment and the material used for fabricating the copings. Brand is not a significant factor in determining retention strength of the copings (Figure 14). The two brands - ADIN and MIS

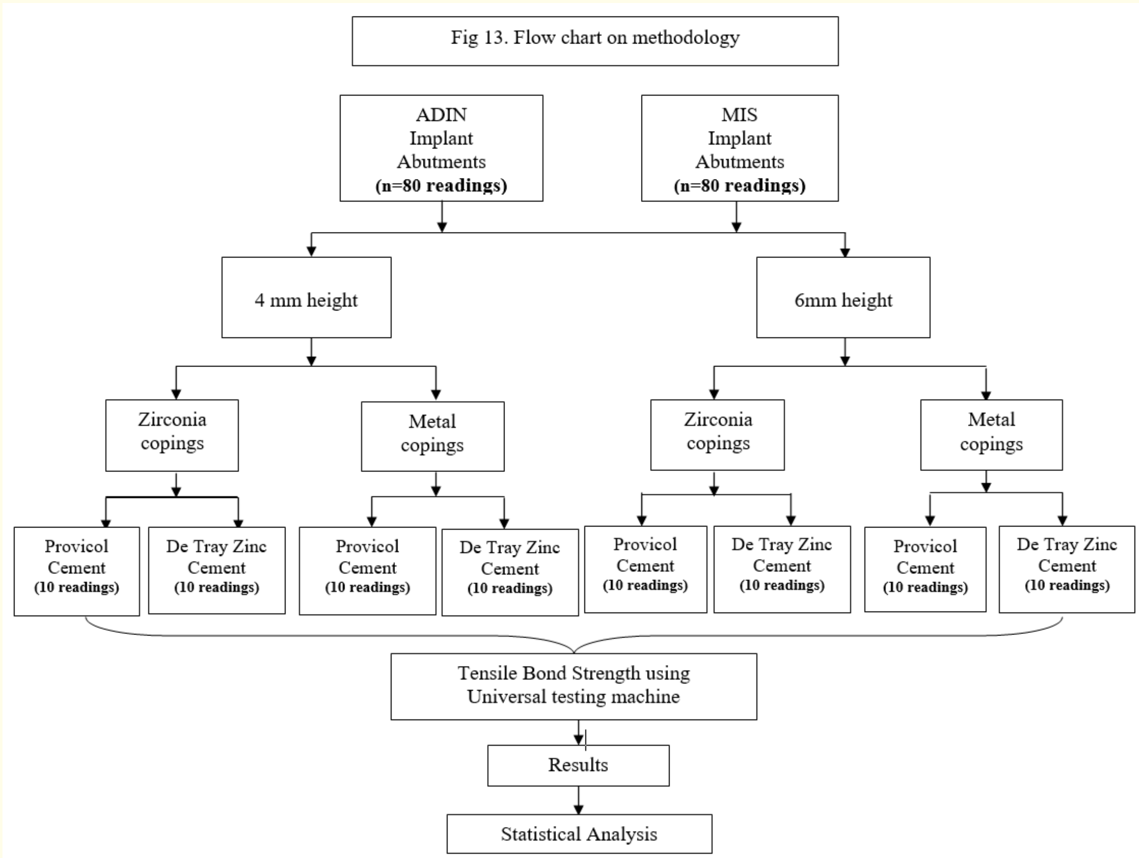

Figure 13: Flow chart on methodology

Factor	Levels
Brand	ADIN, MIS
Coping	Metal, Zirconia
Luting Agent	De Trey Zinc, Provicol
Height	4mm, 6mm

Table 2: Factors and levels used in statistical analysis.

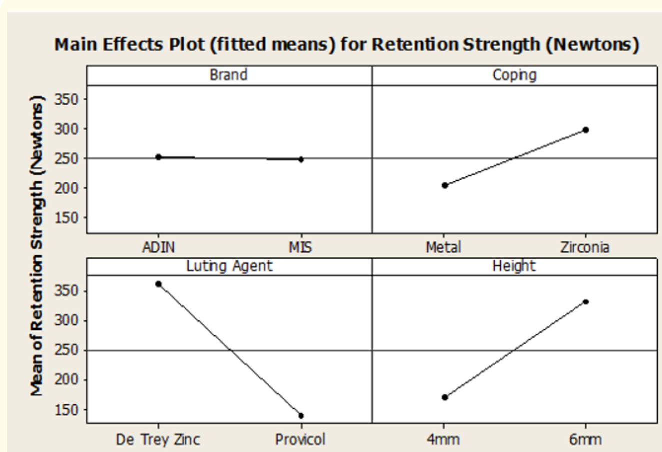

Figure 14: Main Effects Plot which shows the mean retention strength recorded in different levels of each factor.

behaved almost similarly against the type of copings, luting agents and the height of abutments. Zirconia always showed a higher mean retention strength than the metal coping with either of the luting agents as well as with the two different heights of abutments tested in this study. Between the two luting agents, De Trey Zinc always showed higher mean retention strength when used with metal/zirconia copings and 4mm/6mm high abutment. The combination of materials which provided higher mean retention strength would be the use of De Trey Zinc luting agent with Zirconia coping with.

Discussion

Height of the abutment, type of the coping and the luting agents had significant role in determining the retention of copings on implant abutments and hence the related null hypothesis was rejected.

Height of the abutment

On comparing the height of abutments viz. 4mm and 6mm, the latter abutment provided maximum retention. The difference existing between the two heights was statistically significant ($p < 0.001$) (Table 3,4). Other authors also have observed similar retention feature and endorse the present finding [4,6,12,18,21,23]. The increase in bond strength has definite relationship with the increase in surface area. However, availability of restorable space dictates the dimensions of the abutments. The area provided by the abutment for luting is responsible for the retention it provides [37.06mm^2 (4mm) and 48.07mm^2 (6mm)]. The abutments with larger diameter also exhibited superior bond strength; and hence increasing the abutment diameter is recommended when the increase in abutment height is possible [24].

Brand	Coping	Luting Agent	Height	Mean	Std dev	SE of Mean	Median	Min	Max
ADIN	Metal	De Trey Zinc	4mm	212.20	12.58	3.98	210.0	198	243
			6mm	421.20	11.61	3.67	422.0	398	433
		Provicol	4mm	63.20	5.87	1.85	64.5	53	70
			6mm	111.70	6.17	1.95	111.0	103	124
	Zirconia	De Trey Zinc	4mm	272.70	7.89	2.49	271.0	263	287
			6mm	553.90	12.75	4.03	553.0	534	583
		Provicol	4mm	141.80	3.85	1.22	141.5	134	148
			6mm	235.80	4.34	1.37	236.0	228	245
MIS	Metal	De Trey Zinc	4mm	212.80	14.07	4.45	212.5	190	234
			6mm	428.80	25.45	8.05	432.0	386	458
		Provicol	4mm	60.90	5.72	1.81	60.0	55	73
			6mm	114.60	6.48	2.05	115.0	102	123
	Zirconia	De Trey Zinc	4mm	232.70	16.67	5.27	233.5	203	260
			6mm	556.00	27.34	8.65	552.0	508	603
		Provicol	4mm	153.30	6.77	2.14	155.5	143	163
			6mm	227.20	5.69	1.80	227.5	220	237

Table 3: Mean retention strength recorded in combination of different factor-levels (Newton).

Std dev: Standard Deviation; SE of mean: Standard Error of Mean; Min: Minimum; Max: Maximum

Source	df	Sum of Squares (SS)	Mean SS	F	P-Value
Brand	1	429	429	2.59	0.110
Coping	1	349690	349690	2112.81	<0.001*
Luting Agent	1	1984257	1984257	11988.76	<0.001*
Height	1	1055600	1055600	6377.87	<0.001*
Brand x Coping	1	1199	1199	7.24	0.008*
Brand x Luting Agent	1	689	689	4.16	0.043*
Brand x Height	1	731	731	4.42	0.037*
Coping x Luting Agent	1	2839	2839	17.15	<0.001*
Coping x Height	1	37577	37577	227.04	<0.001*
Luting Agent x Height	1	360430	360430	2177.70	<0.001*
Brand x Coping x Luting Agent	1	1464	1464	8.85	0.003*
Brand x Coping x Height	1	60	60	0.36	0.548
Brand x Luting Agent x Height	1	2560	2560	15.47	<0.001*
Coping x Luting Agent x Height	1	8094	8094	48.90	<0.001*
Brand x Coping x Luting Agent x Height	1	2280	2280	13.78	<0.001*
Error	144	23833	166	---	---
Total	159	3831733	---	---	---

Table 4: ANOVA.

*denotes significance.

df: Degree of Freedom; SS: sum of Squares; F: Variance of the Group Means/Mean of the within Group Variances; p-Value: probability of Obtaining the Result

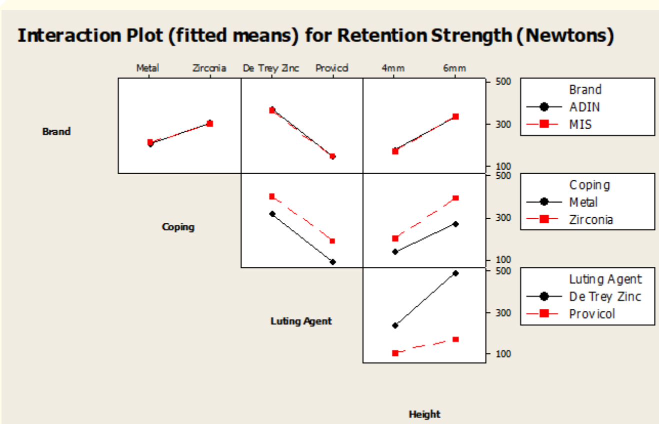

Figure 15: Interactions plot which shows the mean retention strength recorded in combination of different factors and their levels.

Type of copings

Retention of Zirconia and Nickel chromium alloy copings when compared, it was found that Zirconia copings provided superior retention (Table 3,4). The higher bond strength expressed with Zirconia coping was irrespective of the type of luting cement used. The difference existing between the two copings was statistically significant ($p < 0.001$). Similar observations were obtained with other authors also [18,22,24]. The superior retention strength observed with Zirconia copings can be related to the precise fabrication process. Zirconia copings were machined precisely whereas metal copings were fabricated by conventional casting methods [26]. The cement space is arbitrarily made in technician fabricated crowns. The different coats of die spacer applied by the technician is mainly dictated by personal preferences and has the limitations of arbitrariness. In CAD/CAM, the cement space is predetermined and uniformly achieved. The film thickness of luting cement has an influence on the retention which is inversely proportional.

Type of luting agents

On comparing the type of cements viz. Provicol and De Trey Zinc, De Trey Zinc provided maximum retention. The difference that existed between the two cements was statistically significant ($p < 0.001$). Many other authors had similar observations - higher retention values for zinc phosphate cement in comparison to zinc oxide eugenol cement.[5,13-17,19,20]. Zinc Phosphate cement provide retention by micromechanical interlocking it makes into the castings and the abutment surface irregularities. Also, the cement has very high compressive and tensile strength than Zinc Oxide Eugenol cement.

Hallgren [27] and colleagues performed pull-out tests of cylindrical implants inserted into rabbit tibiae. The shear strength required to displace the implant directly out of the socket along its long axis was about 290 N. Though the study was conducted on an animal model it can be considered as a guideline. Singer and Serfaty [28], found 9.8% failure in fixed partial dentures when cemented with temporary cements within 6-months to 3-years. Clinically, cemented prostheses are exposed to repeated masticatory forces, temperature changes and high humidity. These factors may cause a weakening of retention and thereby necessitate frequent re-cementation of implant-supported prostheses. Luting cements should provide optimum retention values and it should be above that of a temporary cement and at the same time well below the force provided by the osseointegration. A cement with retention force that falls between a resin cement and temporary cement will be a rational choice.

In a consensus review published in 2014, cement retention is indicated 'for short span prostheses with margins at or above the mucosa level'. It 'compensates for improperly inclined implants' and 'for cases where an easier control of occlusion without an access hole is desired – for example with narrow diameter crown'. Cement retention is the favourite of implant practitioners because of the ease of operation. The scope of retrievability with cement retained implant crowns is very limited with strong luting agents. The cement excesses that pass to the gingival sulcus is not removed satisfactorily and hence poses a biologic challenge to the implants. Screw retained implant prostheses ensure retrievability, but they challenge the technical soundness of the structure because of the access opening present on the occlusal surface [29].

Taking into consideration of the various factors analysed in the study, when a 4mm abutment is used the luting agent which can be advised is Zinc phosphate cement. When a 6mm abutment is used with Zirconia coping, it is desirable to cement it with Zinc oxide non-eugenol cement to obtain adequate retention without causing problems to the osseointegrated implant. Similarly, when a 6mm abutment is used with Zirconia coping, it is not advisable to cement it with Zinc phosphate cement as retrieval attempts may cause a fatal challenge to osseointegration.

Conclusions

The following conclusions were drawn from the present study

- The two brands of dental implants viz. MIS and ADIN behaved almost in a similar fashion with respect to the variables such as the materials used for preparing the copings, cement used for luting and the height of the abutments.
- Height of the implant abutment and the retention of the copings have a directly proportional relationship.
- While comparing Zirconia and metal copings, the former always exhibited superior retention strength irrespective of the other variables such as luting agents and height of the abutment.
- Between the two luting agents, De Trey Zinc always showed higher mean retention strength when used with metal or Zirconia copings with abutments having 4mm or 6mm height.
- The combination of Zirconia copings, De Trey Zinc luting cement and abutment with 6mm height exhibited a retention strength of 556 ± 27.34N. Retrieval of a crown or a coping with this very high retention strength should be approached with great caution.
- With 4mm abutments, the luting cement that can be recommended is zinc phosphate followed by provisional cement whereas with 6mm abutments, the preferential order has to be reversed. If the retention values are high, retrieval attempts may challenge the osseointegration.

Bibliography

1. Kent DK., *et al*. "Retention of cemented implant-supported restorations". *Journal of Prosthodontics* 6 (1997): 793- 196.
2. 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.
3. Ramp MH., *et al*. "Tensile bond strengths of provisional luting agents used with an implant system". *Journal of Prosthetic Dentistry* 81 (1999): 510-514.
4. Covey DA., *et al*. "Effect of abutment size and luting cement type on the uniaxial retention force of implant-supported crowns". *Journal of Prosthetic Dentistry* 83 (2000): 344-348.
5. Squier RS., *et al*. "Retentiveness of Dental Cements Used with metallic Implant Components". *International Journal of Oral and Maxillofacial Implants* 16 (2001): 793-798.
6. Akca K., *et al*. "Comparison of uniaxial resistance forces of cements used with implant-supported crowns". *International Journal of Oral and Maxillofacial Implants* 17 (2002): 536-542.
7. Mayta-Tovalino FR., *et al*. "Removal force of cast copings to abutments with three luting agents". *Journal of Dental Implants* 5 (2015): 25-30.
8. Angel Alvarez-Arenal., *et al*. "The selection criteria of temporary or permanent luting agents in implant-supported prostheses: *in vitro* study". *Journal of Advanced Prosthodontics* 8 (2016): 144-149.
9. Sara Maria Blender., *et al*. "Effect of abutment height and type of cement". *The International Journal of Prosthodontics* 35 (2022): 442-452.
10. Angel Alvarez-Arenal., *et al*. "The selection criteria of temporary or permanent luting agents in implant-supported prostheses: *in vitro* study". *Journal of Advanced Prosthodontics* 8 (2016): 144-149.
11. Saber FS., *et al*. "Effect of abutment height on retention of single cement-retained, wide- and narrow-platform implant-supported restorations". *Journal of Dental Research Dental Clinics Dental Prospects* 6.3 (2012): 98-102.
12. Bernal G., *et al*. "The effects of abutment taper, length and cement type on resistance to dislodgement of cement-retained, implant-supported restorations". *Journal of Prosthodontics* 12 (2003): 111-115.
13. Bresciano M., *et al*. "Retention of luting agents on implant abutments of different height and taper". *Clinical Oral Implants Research* 16 (2005): 594-598.
14. Yeung TC., *et al*. "The effect of cement and venting design on the retentive strength and marginal adaptation of CeraOne implant prostheses". *Chinese Journal of Dental* 24.2 (2005): 95-100.
15. Maeyama H., *et al*. "Retentive strength of metal copings on prefabricated abutments with five different cements". *Clinical Implant Dentistry and Related Research* 7.4 (2005): 229-234.
16. Pan YH and Lin CK. "The effect of luting agents on the retention of dental implant-supported crowns". *Chang Gung Medical Journal* 28.6 (2005): 403-410.
17. Wolfart M., *et al*. "Retention forces and seating discrepancies of implant-retained castings after cementation". *The International Journal of Oral and Maxillofacial Implants* 21 (2006): 519-525.
18. Abbo B., *et al*. "Resistance to dislodgement of zirconia copings cemented onto titanium abutments of different heights". *Journal of Prosthetic Dentistry* 99 (2008): 25-29.
19. Sheets JL., *et al*. "Cement selection for cement-retained crown technique with dental implants". *Journal of Prosthodontics* 17 (2008): 92-96.
20. Wahl C., *et al*. "Assessment of the tensile strength of hexagonal abutments using different cementing agents". *Brazilian Oral Research* 22.4 (2008): 299-304.
21. Al Hamad KQ., *et al*. "The effects of height and surface roughness of abutments and the type of cement on bond strength of cement-retained implant restorations". *Clinical Oral Implants Research* 22 (2011): 638-644.
22. Nejatidanesh F., *et al*. "Retention of implant supported zirconium oxide ceramic restorations using different luting agents". *Clinical Oral Implants Research* 00 (2011): 1-5.

23. Cano-Batalla J., *et al*. "Influence of abutment height and surface roughness on *in vitro* retention of three luting agents". *International Journal of Oral and Maxillofacial Implants* 27 (2012): 36-41.

24. Sina Safari., *et al*. "Effects of abutment diameter, luting agent type, and re-cementation on the retention of implant-supported CAD/CAM metal copings over short abutments". *Journal of Advanced Prosthodontics* 10 (2018): 1-7.

25. Carnaggio TV., *et al*. "Retention of CAD/CAM all-ceramic crowns on prefabricated implant abutments: an in vitro comparative study of luting agents and abutment surface area". *Journal of Prosthodontics* 00 (2012): 1-6.

26. Deepthi B C., *et al*. "Comparative evaluation of retention of zirconia copings and cast metal copings cemented on to titanium abutments: an *in vitro* study". Journal of Interdisciplinary Dentistry 9 (2019): 8-14.

27. Hallgren C., *et al*. "Histomorphometric and mechanical evaluation of the bone-tissue response to implants prepared with different orientation of surface topography". *Clinical Implant Dentistry and Related Research* 3.4 (2001): 194-203.

28. Singer A and Serfaty V. "Cement-retained implant-supported fixed partial dentures: a 6-month to 3-year follow-up". *International Journal of Oral and Maxillofacial Implants* 11 (1996): 645-664.

29. Wismeijer D., *et al*. "Consensus statements and recommended clinical procedures regarding restorative materials and techniques for implant dentistry". *International Journal of Oral and Maxillofacial Implants* 29 (2014): 137-140.