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Evaluation of the Retention of Cast Copings with Different Lengths, Tapers and Luting Agents

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Abstract

This study includes a comparative evaluation and a general conclusion about the best advisable crown length, taper and cement for maximal retention. One hundred and twenty extracted human maxillary premolar teeth with sound surfaces were selected using dial vernier calliper. Selected teeth were randomly divided into two different CO length groups (5 mm and 7 mm). Each group was randomly divided into 4 sub groups according different degree of taper of the axial wall (0°, 3°, 6°, 9°). The crown preparations with different tapers were achieved by graduated customized device. Preparations were verified and crowns were cast with Co–Cr alloy; metal copings were luted with GIC, RMGIC and self adhesive resin cement. Retention was measured (MPa) by separating the metal crowns from the teeth under tension on a universal testing machine, data was recorded and statistically analyzed. Increasing the crown height from 5mm to 7mm, significantly increased the tensile bond strength of cast copings among all degrees of taper. Tensile bond strength in 0° taper was significantly higher than 3°, 6° and 9° taper. Resin cement showed significantly higher retentive strength than GIC and RMGIC.

Keywords: Self adhesive resin cement; Glass ionomer cement; Retention; Taper.

INTRODUCTION

A crown may be recommended to increase the tooth's longevity and optimize the patient's oral health. For their fabrication, porcelain fused to metal (PFM) crowns have been used for many years and studied extensively with good long term clinical reliability.[1] A sound tooth preparation is required for the success of a restoration. Among the principles of tooth preparation, preparation geometry is the only factor that can be controlled entirely by the operator, which includes taper and surface area of the preparation as important variables.[2] Crown length may often be compromised due to caries or trauma and may not always be in the operator's control. Dental cements are joining medium which provides adhesion or micro-mechanical attachment to the surfaces to be joined[3], like indirect restorations and tooth surface. GIC is based on acid base reaction whereas in RMGIC, polymerizable functional groups were added to

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the conventional glass ionomer cements to achieve rapid curing activated by light/chemical while still allowing acid base reaction to take its course along with the polymerization.[4] Adhesive monomers have been added in Resin cements to enable chemical bonding to both the tooth structure and the suitably prepared metal surfaces.[5] Factors like crown length, taper and luting cement together play an important role in the retention of the prosthesis.

METHODOLOGY

120 single rooted maxillary 1st premolars, extracted for periodontal or orthodontic reasons, were collected after excluding teeth with caries and/or previous restorations. After removing dental plaque, calculus, and periodontal tissues with ultrasonic instruments and curettes, the teeth were stored in physiological solution (artificial saliva) until further use. Self curing acrylic resin block was made using a stainless steel jig (Fig. 1). For the purpose of the study, the root of each tooth was embedded in the acrylic resin block, up to 2 mm below the cementoenamel junction (CEJ) with its long axis perpendicular to the base of the block (Fig. 2). Preparation of the teeth was standardized using a diamond bur mounted onto a customized graduated device (Fig. 3) using a surveyor.

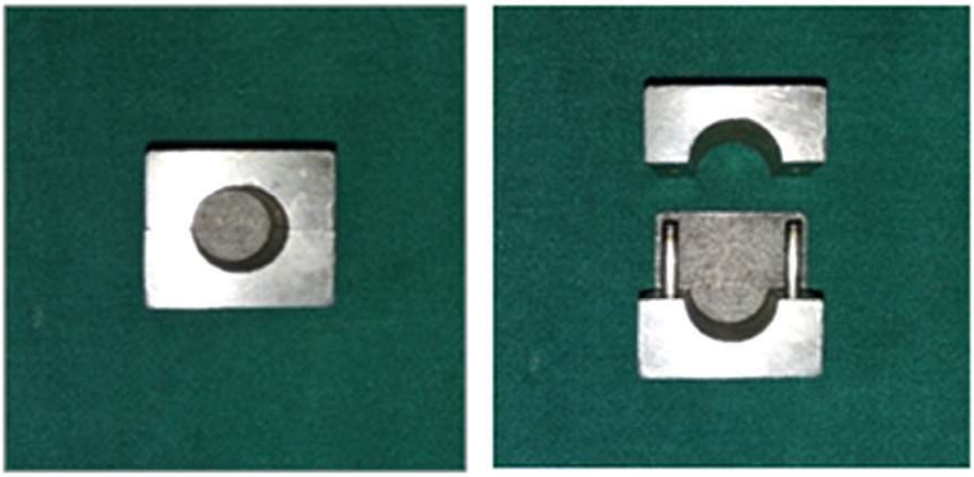


Fig. 1: Stainless Steel Jig

Fig. 2: Tooth embedded in acrylic block

Fig. 3: Customised graduated device

The samples were randomly divided into 2 groups (n = 60) according to the cervico-occlusal length of the crown to be prepared, Group A: 5mm length, Group B: 7mm length. Each group was randomly divided into 4 sub-groups (n=15) according different degree of taper of the axial wall, Sub group 1: Zero degree, Sub group 2: 3 degrees, Sub group 3: 6 degrees, Sub group 4: 9 degrees (Fig. 4). A coping was waxed on each tooth (Fig. 5) and then casted with Co-Cr alloy by Induction casting method (Fig. 6). The sub-groups were randomly divided into 3 sub-sub groups (n = 5) according to different cementation systems for Glass Ionomer Cement, Resin Modified Glass Ionomer Cement and Self Adhesive Resin Cement.

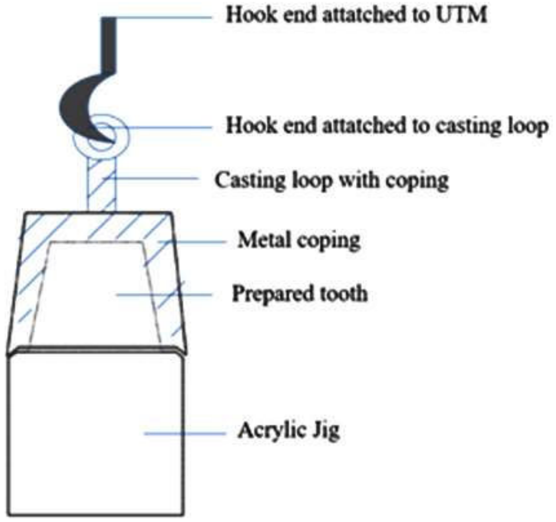
Fig. 4: Prepared tooth

Fig. 5: Wax pattern

Fig. 6: Final casting for sample

Method of testing: An iron rod with hooks at either end was attached to the loop casted on the occlusal surface of the metal coping at one end and to the Universal testing machine at the other end and was pulled (Fig. 7).

Fig. 7: Pull- off test on UTM



Tensile load of 500kN at cross head speed of 0.5 mm per minute was applied. The breaking load (kg) was investigated by using universal testing machine when the casting was separated from the tooth. Failure mode was classified as decementation and the failure load data was recorded for each sample and were analyzed using one-way analysis of variance (ANOVA). The failure load (kg) was converted to Tensile strength (MPa) by the following equation.

RESULTS

The statistical procedure was carried out in 2 steps.

- Data compilation and presentation
- Statistical analysis

Inferential statistical analysis has been carried out in the present study. Results on continuous measurements are presented on Mean ± SD (Min-Max). Significance is assessed at 5% level of significance. ANOVA with post hoc bonferroni for multiple comparisons tests has been used to find the significance of study parameters on ordinal scale between more than two groups.

Table 1: Fail Force

Group	Sub Group	Fail Force (Kg)						ANOVA (F)	p - Value
		GIC		RMGIC		Resin Cement			
		Mean	SD	Mean	SD	Mean	SD		
5 mm	0 Degree	57.84	1.31	68.25	1.02	78.84	0.71	506.280	< 0.001 (VHS)
	3 Degree	53.76	0.17	64.30	1.22	76.21	0.75	914.336	< 0.001 (VHS)
	6 Degree	45.97	0.21	56.91	0.14	68.65	0.48	6490.864	< 0.001 (VHS)
	9 Degree	39.80	0.99	45.04	0.81	54.58	0.37	477.632	< 0.001 (VHS)
7 mm	0 Degree	62.50	0.54	74.81	0.53	84.00	0.20	2835.156	< 0.001 (VHS)
	3 Degree	59.00	0.28	70.57	0.50	80.14	1.25	888.364	< 0.001 (VHS)
	6 Degree	53.96	0.80	64.58	0.50	75.42	0.32	1751.223	< 0.001 (VHS)
	9 Degree	46.88	0.66	51.84	0.36	60.29	0.59	753.311	< 0.001 (VHS)
ANOVA (F)		**555.192**		**985.510**		**1205.651**			
p - Value		**< 0.001 (VHS)**		**< 0.001 (VHS)**		**< 0.001 (VHS)**			

SD – Standard Deviation, VHS – Very Highly Significant

Table 1: (a) Multiple Comparisons (post hoc bonferroni)

	Group	0 Degree (p – Value)	3 Degree (p – Value)	6 Degree (p – Value)	9 Degree (p – Value)
5 mm	GIC vs RMGIC	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	GIC vs Resin Cement	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	RMGIC vs Resin Cement	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 1(b): Multiple Comparisons (post hoc bonferroni)

	Group	0 Degree (p – Value)	3 Degree (p – Value)	6 Degree (p – Value)	9 Degree (p – Value)
7 mm	GIC vs RMGIC	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	GIC vs Resin Cement	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	RMGIC vs Resin Cement	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 1(c): Multiple Comparisons (post hoc bonferroni)

Group		GIC (p – Value)	RMGIC (p – Value)	Resin Cement (p – Value)
5 mm	0 Degree vs 3 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	0 Degree vs 6 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	0 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	3 Degree vs 6 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	3 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	6 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 1(d): Multiple Comparisons (post hoc bonferroni)

Group		GIC (p – Value)	RMGIC (p – Value)	Resin Cement (p – Value)
7 mm	0 Degree vs 3 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	0 Degree vs 6 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	0 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	3 Degree vs 6 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	3 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	6 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 1(e): Multiple Comparisons (post hoc bonferroni)

Group		GIC (p – Value)	RMGIC (p – Value)	Resin Cement (p – Value)
0 Degree	5mm vs 7 mm	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
3 Degree	5mm vs 7 mm	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
6 Degree	5mm vs 7 mm	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
9 Degree	5mm vs 7 mm	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 2: Tensile strength

Group	Sub Group	Tensile strength (MPa)						ANOVA (F)	p - Value
		GIC		RMGIC		Resin Cement			
		Mean	SD	Mean	SD	Mean	SD		
5 mm	0 Degree	2.07	0.045	2.44	0.035	2.92	0.024	549.5	< 0.001 (VHS)
	3 Degree	2.02	0.007	2.42	0.048	2.87	0.028	896.5	< 0.001 (VHS)
	6 Degree	1.91	0.008	2.37	0.007	2.86	0.022	5329.1	< 0.001 (VHS)
	9 Degree	1.77	0.044	2	0.036	2.43	0.017	467.6	< 0.001 (VHS)
7 mm	0 Degree	1.86	0.018	2.23	0.014	2.5	0.005	2683.8	< 0.001 (VHS)
	3 Degree	1.84	0.008	2.2	0.016	2.5	0.038	934.7	< 0.001 (VHS)
	6 Degree	1.79	0.028	2.15	0.018	2.49	0.010	1634.0	< 0.001 (VHS)
	9 Degree	1.74	0.025	1.92	0.013	2.23	0.021	688.2	< 0.001 (VHS)
ANOVA (F)		104.570		339.952		537.615			
p - Value		< 0.001 (VHS)		< 0.001 (VHS)		< 0.001 (VHS)			

SD – Standard Deviation, VHS – Very Highly Significant

Table 2 (a): Multiple Comparisons (post hoc bonferroni)

Group		0 Degree (p – Value)	3 Degree (p – Value)	6 Degree (p – Value)	9 Degree (p – Value)
5 mm	GIC vs RMGIC	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	GIC vs Resin Cement	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	RMGIC vs Resin Cement	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 2 (b): Multiple Comparisons (post hoc bonferroni)

Group		0 Degree (p – Value)	3 Degree (p – Value)	6 Degree (p – Value)	9 Degree (p – Value)
7 mm	GIC vs RMGIC	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	GIC vs Resin Cement	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	RMGIC vs Resin Cement	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 2 (c): Multiple Comparisons (post hoc bonferroni)

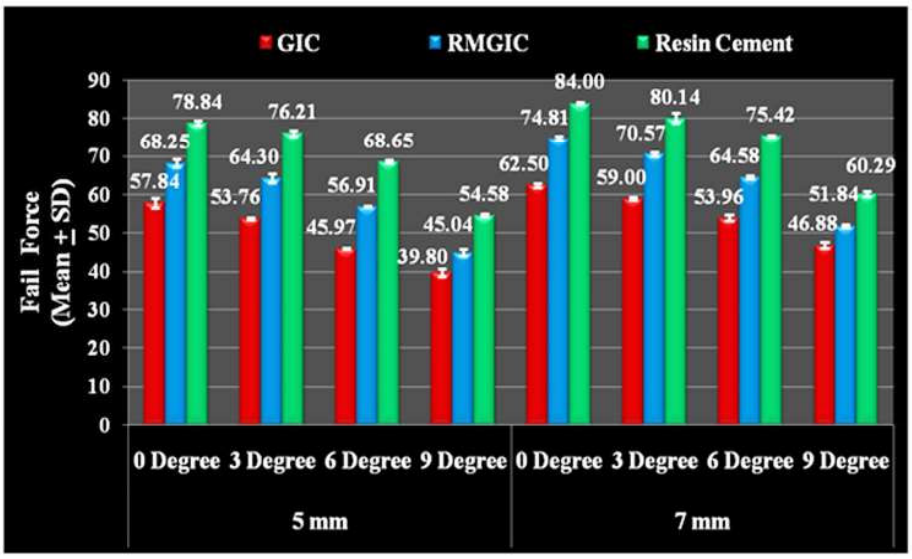
Group		GIC (p – Value)	RMGIC (p – Value)	Resin Cement (p – Value)
5 mm	0 Degree vs 3 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	0 Degree vs 6 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	0 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	3 Degree vs 6 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	3 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	6 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 2 (d): Multiple Comparisons (post hoc bonferroni)

Group		GIC (p – Value)	RMGIC (p – Value)	Resin Cement (p – Value)
7 mm	0 Degree vs 3 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	0 Degree vs 6 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	0 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	3 Degree vs 6 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	3 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
	6 Degree vs 9 Degree	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)

Table 2 (e): Multiple Comparisons (post hoc bonferroni)

Group		GIC (p – Value)	RMGIC (p – Value)	Resin Cement (p – Value)
0 Degree	5mm vs 7 mm	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
3 Degree	5mm vs 7 mm	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
6 Degree	5mm vs 7 mm	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)
9 Degree	5mm vs 7 mm	< 0.001 (VHS)	< 0.001 (VHS)	< 0.001 (VHS)



Graph 1: Mean fail force in Kgs

Graph 1 and Table 1 shows force at failure required to separate the cast copings from the respective samples. Failure load (kg) was found to be in the following decreasing order.

Self Adhesive Resin Cement (RC) > Resin Modified Glass Ionomer Cement (RMGIC) > Glass Ionomer Cement (GIC)

The pattern follows the same decreasing order for all tapers of 0 degree, 3 degree, 6 degree and 9 degree and for both CO length of 5mm and 7mm used in this study.

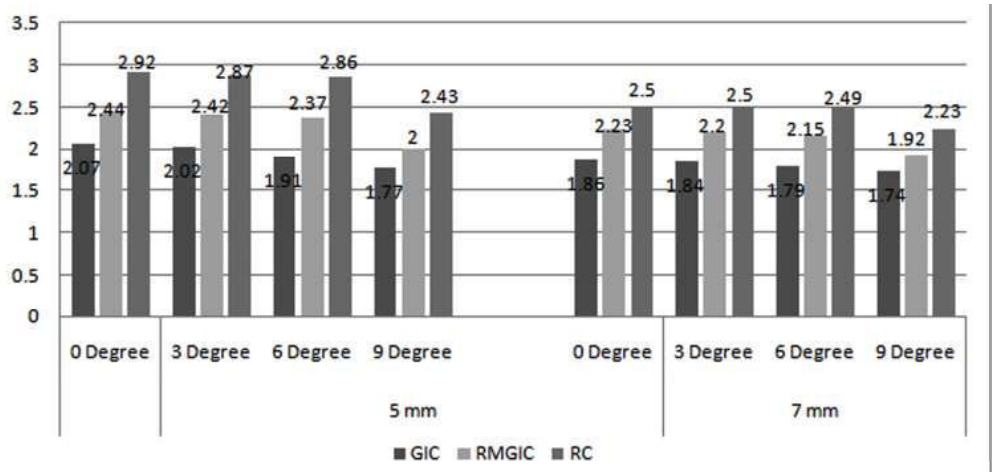
5mm > 7mm

The pattern follows the same decreasing order for all tapers of 0 degree, 3 degree, 6 degree and 9 degree and for all cement groups - GIC, RMGIC, RC used in this study.

0-degree > 3-degree > 6-degree > 9-degree

The pattern follows the same decreasing order for all cement groups- GIC, RMGIC,

RC and for both CO length of 5mm and 7mm used in this study.



Graph 2: Mean tensile strength in MPa

Graph 2 and Table 2 shows tensile strength exhibited by the cast copings on the respective samples. Tensile strength (MPa) was found to be in the following decreasing order

Self Adhesive Resin Cement (RC) > Resin Modified Glass Ionomer Cement (RMGIC) > Glass Ionomer Cement (GIC)

The pattern follows the same decreasing order for all tapers of 0 degree, 3 degree, 6 degree and 9 degree and for both CO length of 5mm and 7mm used in this study.

5mm > 7mm

The pattern follows the same decreasing order for all tapers of 0 degree, 3 degree, 6 degree and 9 degree and for all cement groups - GIC, RMGIC, RC used in this study.

0-degree > 3-degree > 6-degree > 9-degree

The pattern follows the same decreasing order for all cement groups - GIC, RMGIC, RC and for both CO length of 5mm and 7mm used in this study.

DISCUSSION

Crowns and fixed partial dentures are the major prosthodontic treatment modalities for past several decades with factors like esthetics, contact points and pontics playing an important role in varying their design. Retention prevents removal of the restoration along the path of insertion or long axis of the tooth preparation.[6] The geometric configuration of the tooth preparation must place the cement in compression to provide the necessary retention and resistance.[7] Based on researches, loss of crown retention has been the second leading cause of failure of crowns and fixed partial dentures.[8] Crown displacement often occurs because the features of the tooth preparation do not counteract the forces directed against the restorations. Therefore, the design of the tooth preparation is an important consideration in tooth reconstruction.

In this study, extracted human premolars were chosenorder to match the qualities of natural healthy teeth pertaining to their properties like modulus of elasticity (MOE), strength and bonding capacity to dental cements.[9] Artificial saliva storage produces one third less cell damage than dry storage or storage in tap water, so it is preferable to use it rather than keep the tooth in dry conditions.[10]

The results of this study depicted that the retentive strength of indirect restorations increased drastically with an increase in the axial wall length of the prepared tooth in case of cast copings.

Longer preparations will have more surface area than a preparation with reduced height. Also, by increasing the preparation height, the number of paths along which a restoration can be removed from the tooth preparation are limited geometrically. Maximum retention is achieved when there is only one path.[11] Increasing the crown height also limits the freedom of displacement from torquing or twisting forces in a horizontal plane.[12]

The results of this study also depicted that as the taper of the preparation was increased from 0^o to 3^o, 6^o and 9^o, retention of the cast copings decreased. Lesser the taper, more is the diameter of the tooth, hence there is an increase the surface area of the preparation. Axial wall with a smaller taper will be more nearly close to a perpendicular wall required to resist crown displacement when under masticatory forces. Also, a crown with increased taper will have more number of path of removal as compared to lesser degree of taper.[11]

On evaluating the retentive strength of various luting agents considered in this study, the samples luted with Glass ionomer cement showed least retention, followed by Resin modified Glass ionomer cement and the highest retentive strength was exhibited by self adhesive resin cement. All resin cements form a hybrid layer which at the molecular level is a mixture of collagen and resin polymers. The self adhesive resin cement exhibit better adhesion due to the fact that the functional phosphoric acid methacrylates demineralizes the dentin and reacts with inorganic fillers present in the tooth substrate to create the hybrid layer. This characteristic improves the micromechanical retention.[13]

The type of luting agent chosen affects the retention of a cemented restoration. However, changes in preparation geometry plays a major role in the retention of the restoration and an optimum relationship should be maintained between all these factors for the success of the restoration.

CONCLUSION

Within the limitations of this study, following observations can be made:

- Increasing the crown height from 5mm to 7mm, significantly increased the tensile bond strength of cast copings among all degrees of taper considered in this study.
- Among all degrees of taper used in the current study, the pattern seen in tensile bond strength was observed to be $0^o > 3^o > 6^o > 9^o$
- Increasing the taper of the preparation from 0-degree to 3-degree or 6-degree had a significant effect on the retention of copings within different cement groups and increasing the taper to 9-degree further showed a decrease in the retention of copings significantly.
- Among all luting agents considered in this study, tensile bond strength was found to be in a pattern: Self adhesive resin cement > Resin modified glass ionomer cement > Glass ionomer cement.
- On Intra-group analysis, with a constant cervico-occlusal height of 5mm, cast copings luted with resin cement, having 0-degree taper showed the maximum breaking load (78.84 kg /2.92 MPa), whereas cast copings luted with GIC having 9-degree taper showed the minimum breaking load (39.80 kg /1.77 MPa).
- On Intra-group analysis, with a constant cervico-occlusal height of 7mm, cast copings luted with resin cement having 0-degree taper showed the maximum breaking load (84.00 kg /2.43 MPa), whereas cast copings luted with GIC having 9-degree taper showed the minimum breaking load (46.88 kg /1.74 MPa)

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