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Effect of Different Luting Agents on the Retention of Cast Metal Complete Crowns Prepared with Different Surface Textures: An in Vitro Study

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Abstract: ***Objective:*** ***To evaluate the influence of tooth surface textures prepared with diamond rotary instruments on the retention of cast metal complete crowns cemented with five different luting agents. Method: One hundred and fifty intact human molar teeth were prepared into three equal groups of different surface textures such as, Coarse, Regular, and Fine using diamond rotary cutting instruments of respective grit sizes. Teeth preparation with standard finish line and axial inclination were performed using Milling machine. Axial surface areas of prepared tooth specimens were measured using software called AutoCAD. Cast crowns of each group were cemented with five luting agents namely: zinc phosphate (Harvard), zinc polycarboxylate (Poly-F), glass ionomer (GC Fuji-I), resin modified glass ionomer (3M Vitremer,) and adhesive resin cement (3M- Rely-X ARC). The testing of the specimens to determine the tensile bond stress of cemented crowns was performed with a Hounsfield Tensometer unit. Results: Statistical analysis of tensile stress indicated a very highly significant (p<0.001) influence of prepared tooth surface textures on the retentive capacities of the luting agents. Conclusion: 3M-Rely-X and Harvard cement demonstrated greater retention of cast complete crowns cemented to tooth surface finished with coarse grit diamond. GC Fuji-I demonstrated greater retention of the crowns to tooth surfaces finished with fine grit diamond. Poly-F and 3M-vitremer demonstrated their highest retentive capacities to tooth preparation finished with regular grit diamond.***

Keywords: Surface texture, retention, luting agents, axial surface area, tensile stress

1. Introduction

Loss of retention has been reported as one of the leading cause for failure in crown and fixed partial denture prosthesis. Many factors have been demonstrated to influence the retention of cast metal crowns, such as the size, shape, and surface roughness of the prepared teeth; manipulation, application, retentive properties, and film thickness of the luting agent. Kaufman EG et al (1961)[1] grouped the factors that influence the retention of complete metal crown into three categories, such as: (I) factors related to tooth preparation, (II) factors related to casting, and (III) factors related to cementing medium. An ideal luting agent should provide a durable bond between dissimilar materials; possess favorable compressive and tensile strength, and have sufficient fracture toughness to prevent dislodgement as a result of interfacial and cohesive failures [2], [3], [4]. The two primary adhesive mechanisms of dental cements are mechanical interlocking and physiochemical bonding [5]Ayad et al (1996) reported that surface roughness of tooth preparation that encourages mechanical interlocking of cement may enhance retention and reduce the need for additional retentive measures [6]. Both carbide and diamond rotary instruments are used for tooth preparation. Carbide burs cut both enamel and dentin efficiently with less heat generation and produce smoother surface than the diamond instruments [7]. However, there is not enough documented report in the dental literature to support the selection of luting agent and type of rotary diamonds that are use to prepare and finish the tooth preparation for complete cast crown restoration. Hence, this study is designed to determine the relationship between the tooth surface textures prepared for cast metal complete crown with diamond rotary instruments and retentive capacities of luting agents.

2. Objectives

The study was undertaken with the following objectives:

1) To determine the retentive tensile stresses of cast metal complete crowns luted on teeth prepared and finished with three different diamond rotary instruments, such as coarse, regular, and fine using five different luting agents, namely: zinc phosphate, zinc poly-carboxylate, glass ionomer, resin modified glass ionomer and resin adhesive cement.
2) To compare the retentive values of respective cemented cast metal complete crowns.
3) To evaluate the influence of the surface textures of the prepared teeth on the retentive capacities of the luting agents used for cementation of the respective complete cast metal crowns.

3. Methodology

Preparation of specimens: One hundred and fifty freshly extracted intact human molar teeth of approximately same crown size were collected. Teeth were cleaned of surface debris; disinfected with 0.5% sodium hypochlorite and then stored in distilled water at room temperature. The cementoenamel junction of each tooth was outlined using permanent marker. In order to align the tooth vertically so that its long axis passes through the area of furcation, a PINDEX SYSTEM (Mark, Coltene/Whaltane Inc.) was used.(Fig.1) The crown of each tooth was then embedded in plaster of paris up to 2mm from the cementoenamel junction using a metal fixture. After setting of the plaster, another screw-system metal fixture was placed over the first metal fixture and the roots of every tooth specimen was then incorporated into self- cured acrylic resin aligning each tooth vertically parallel to its long axis (fig- 2). Teeth were randomly selected to form three equal groups: A, B, and C, according to the surface textures to be produced by diamond cutting tools after tooth preparation to receive complete metal cast crowns. Coarse (125µm, SharpcutTM, Dentsply Asia), Regular (90µm, SharpcutTM, Dentsply Asia), and fine (53µm, SharpcutTM, Dentsply Asia) grit diamond cutting instruments were chosen for preparation and finishing of teeth specimens to produce the desired surface textures. The axial reduction was carried out by using milling machine (Kavo-Elektrotechnisches Werk GmbH, leutkirch im Allgau, West Germany, typ-990, Bestell-Nr.6250200) to standardized the degree of taper and finish line. Surface textures of prepared teeth were examined under stereo electronic microscope to see the surface profiles of the prepared tooth specimens.

Determination of the axial surface area:

1) The prepared tooth specimen was placed on a surface plate.
2) Using a Vernier height gauge with digital read out (MITUTOYO, JAPAN fig-3) the occluso- cervical height of tooth preparation was measured clockwise at 10 different locations of the preparation.
3) Initially the digital read out of the Vernier height gauge was set to zero when the measuring jaw of the height gauge was touching the preparation's finish line at a particular point.
4) The Vernier height gauge measuring jaw was raised until it was just little above the occlusal surface of the preparation.
5) The circumference of the prepared teeth specimen was measured using an inextensible wire. This length was measured using a Vernier caliper (MITUTOYO, JAPAN, fig- 4).
6) The axial surface area of each prepared tooth specimen was obtained using software called AutoCAD.

Fabrication of crowns:

Impressions of the prepared teeth were made with regular and light- bodied polyvinyl siloxane (Aquasil TM, DENTSPLY caulk, USA, LOT-031205). The impressions were poured in type IV die stone (Silky Rock Yellow, Whipmix, Louisville, Ky.) to prepare working dies. The dies were ditched and then painted with 4 coats of die-spacer (Pico-Fit, Set No.1954-0400, Renfert GmbH, and Germany). Gold and silver die-spacer colors were alternately painted to prevent repeated applications. Wax patterns for crowns were prepared with Crown wax (BEGO, Best Nr.40111, and LOT-461, made in Germany), with a thickness of approximately 0.5 to 1mm after lubrication of the dies with die lubricant (Dielube wax sep, Dentecon,Inc. USA). A wax loop was then prepared in the center of the occlusal surface of each wax pattern to facilitate connection of the crown to the tensile testing machine. Wax patterns were immediately sprued and then invested in phosphate bonded investment (Bellagium, BEGO, made in Germany). The wax pattern burnout was performed at 350◦C for 30 minutes. The investments were heated to 850◦C and held for 30 minutes. Crowns were cast in non precious casting alloy (Wirolloy, BEGO, Best Nr.50140, made in Germany) with an electronic induction casting machine (Degutron, Degussa AG, made in Germany).

Luting of the crowns:

Casting were checked for seating discrepancies with a disclosing medium (Fit checker, GC). Internal surfaces of the crowns were cleaned with a steam cleaner set at 70 psi pressure. Five luting agents, namely: zinc phosphate (Harvard cement, Harvard Dental GmbH), zinc poly-carboxylate(Poly-F, DeTrey Dentsply), glass ionomer(GC Fuji-I, GC corporation), resin modified glass ionomer(3M-Vitremer, 3M Dental product) and resin adhesive cement(3M Rely-X ARC, 3M Dental product) was used to lute the crowns (fig-5). Ten specimens from each group were randomly selected for one luting agent and thus cementation of fifty crowns in the group was carried out using above mentioned five luting agents.

Testing for tensile bond stress:

The testing of the specimens for tensile bond stress was performed with a Hounsfield Tensometer (serial No. 6907, Tensometer Ltd., 81. Morland Road, England, (fig-6) unit. Each specimen was aligned in the center of attachment of the testing unit. A uniform tensile load was applied at a constant crosshead speed of 1mm/min. The maximal tensile force used to separate the crown was recorded. In addition, the separated crowns and axial walls of the preparations were examined under stereo electronic microscope to see the mode of failure. Four failure modes were defined

1) Root fractures were defined as cohesive failure of dentin while the crown remained luted in place.
2) Failure at the metal-cement interface was defined when greater than 75% of the luting agent remained on the axial walls of the prepared tooth.
3) Failure at the dentin- cement interface indicates presence of greater than 75% of cement on the internal metal surface of the casting.
4) If neither the dentin nor the casting had a clear preponderance of retained cement, that is, less than 75% of cement was retained; the failure was defined as mixed.

Data thus collected from this study were subjected to statistical analysis.

Figure 1: Pindex System (Mark, Coltene/Whaltane Inc.)

Figure 2: Tooth specimen into self- cured acrylic resin

Figure 3: Digital read out (MITUTOYO, JAPAN)

Figure 4: Vernier caliper (MITUTOYO, JAPAN)

Figure 5: Luting cements used

Figure 6: Hounsfield Tensometer

4. Results

The mean tensile stress and associated standard deviation exhibited by each luting agent in Group-A, Group-B, and Group-C are seen Table I to Table III

Table I: Tensile stress and associated standard deviation in MPa exhibited by each luting agent in Group-A (Coarse surfaces)

Luting agents	No.	Mean	Standard Deviation
Zinc phosphate	10	5.0380	0.5416
Poly carboxylate	10	3.2543	0.3611
GIC	10	3.8336	0.3642
RM-GIC	10	4.8366	0.8381
Resin adhesive	10	6.269	0.3502

Table II: Mean tensile stress and associated standard deviation in MPa, exhibited by each luting agent in Group-B (Regular surfaces)

Luting agents	No.	Mean	Standard Deviation
Zinc phosphate	10	2.8676	0.2187
Poly carboxylate	10	4.9560	0.8187
GIC	10	5.2520	0.4872
RM-GIC	10	7.0450	0.3962
Resin adhesive	10	5.7000	0.5457

Table III: Tensile stress and associated standard deviation in MPa exhibited by each luting agent in Group-C (Fine surfaces)

Luting agents	No.	Mean	Standard Deviation
Zinc phosphate	10	2.4880	0.1891
Poly carboxylate	10	2.5560	0.6204
GIC	10	5.7090	0.7294
RM-GIC	10	4.0030	0.9306
Resin adhesive	10	5.3550	0.5421

Table IV: Comparison of mean tensile stress of Zinc phosphate with other 4 luting agents within Group-A, B, and C using "Mann-Whitney 'U' test", showing its Z and p values

	Group	Poly carboxylate	GIC	RM-GIC	Resin adhesive
A	Z	3.782	3.485	0.378	3.631
	p	0.000 vhs	0.000 vhs	0.705 ns	0.000 vhs
B	Z	3.784	3.784	3.785	3.784
	p	0.000 vhs	0.000 vhs	0.000 vhs	0.000 vhs
C	Z	0.718	3.781	3.781	3.781
	p	0.473 ns	0.000 vhs	0.000 vhs	0.000 vhs

Z= "Mann Whitney 'U' test" value, p= level of significance, vhs=very highly significant, ns= not significance.

Table V: Comparison of mean tensile stress of Poly carboxylate with other 3 luting agents within Group-A, B, and C using "Mann-Whitney 'U' test", showing its Z and p values

	Group	GIC	RM-GIC	Resin adhesive
A	Z	2.576	3.784	3.782
	P	0.000 vhs	0.000 vhs	0.000 vhs
B	Z	0.605	3.784	2.043
	p	0.545 ns	0.000 vhs	0.041 sig
C	Z	3.781	3.630	3.781
	p	0.000 vhs	0.000 vhs	0.000 vhs

sig=just significance

Table VI: Comparison of mean tensile stress of GIC with other 2 luting agents within Group-A, B, and C using “Mann-Whitney ‘U’ test”, showing its Z and p values

	Group	RM-GIC	Resin adhesive
A	Z p	2.501 0.012 sig	3.788 0.000 vhs
B	Z P	3.784 0.000 vhs	1.967 0.049 sig
C	Z p	3.102 0.002 hs	1.286 0.198 ns

Table VII: Comparison of mean tensile stress of Resin modified GIC with Resin adhesive within Group-A, B, and C using “Mann-Whitney ‘U’ test”, showing its Z and p values

	Group	Resin adhesive
A	Z p	3.557 0.000 vhs
B	Z p	3.633 0.000 vhs
C	Z p	2.496 0.013 sig

Table VIII: Comparison of mean tensile stress of each luting agent between Group-A and Group-B with “Mann-Whitney ‘U’ test” showing its Z and p values

	Luting agents	
Zinc phosphate	Z p	3.784 0.001 vhs
Poly-carboxylate	Z p	3.556 0 .001 vhs
GIC	Z p	3.788 0.001 vhs
RM-GIC	Z p	3.785 0.001 vhs
Resin-adhesive	Z p	2.194 0.028 hs

hs= highly significant, ns= non significant

Table IX: Comparison of mean tensile stress of each luting agent between Group-B and Group-C with “Mann-Whitney ‘U’ test” showing its Z and p values

	Luting agents	
Zinc phosphate	Z p	3.026 0.002 hs
Poly-carboxylate	Z p	3.781 0.001 vhs
GIC Z	p	1.476 0.14 ns
RM-GIC	Z p	3.784 0.001 vhs
Resin-adhesive	Z p	1.589 0.112 ns

Table X: Comparison of mean tensile stress of each luting agent between Group-A and Group-C with “Mann-Whitney ‘U’ test” showing its Z and p values

	Luting agents	
Zinc phosphate	Z p	3.781 0.002 vhs
Poly-carboxylate	Z p	2.496 0.013 sig
GIC	Z p	3.788 0.001 vhs
RM-GIC	Z p	2.195 0.028 sig
Resin-adhesive	Z p	2.950 0.003 hs

Table XI: Comparison of mean tensile stress of the individual luting agent among groups with “Kruskal-Wallis” test, showing mean tensile stress and associated std. deviation, H and p values

Group and Luting agent		No.	Mean	Std. Deviation	H	p
Harvard	A	10	5.0380	0.5416	23.50	0.001
	B	10	2.8676	0.2187		
	C	10	2.4880	0.1891		vhs
Poly-F	A	10	3.2543	0.3611	21.29	0.001
	B	10	4.9560	0.8187		
	C	10	2.5560	0.6204		vhs
GC Fuji-I	A	10	3.8336	0.3642	20.37	0.001
	B	10	5.2520	0.4872		
	C	10	5.7090	0.7294		vhs
3M-Vitrem	A	10	4.8366	0.8381	21.55	0.001
	B	10	7.0450	0.3962		
	C	10	4.0030	0.9306		vhs
3M-Relyx	A	10	6.2969	0.3502	10.70	0.005
	B	10	5.7000	0.5457		
	C	10	5.3550	0.5421		hs

H= “Kruskal-Wallis” test value, vhs- very highly significant, hs- highly significant

5. Discussion

This in-vitro study was conducted to investigate the relationship between the retentive capacities of five luting agents and three tooth surface texture forms prepared with diamond rotary cutting instruments of different grit sizes such as coarse, regular and fine. This indicates the influence of prepared tooth surface textures on the retentive capacities of the five luting agents used in this study. Zinc phosphate (Harvard) cement exhibited its highest retentive stress to tooth surfaces finished with Coarse (125µm) grit diamond and lowest retentive stress to tooth surfaces finished with Fine (53µm) grit diamond. Zinc phosphate does not chemically bond to any substrate; it provides retention by mechanical means only. Diamond rotary cutting instruments produce mechanical projections on the prepared tooth surface. The greater retention of complete cast metal crown to coarse surface when luted with zinc phosphate (Harvard) cement may be due to the greater mechanical retentive areas at the dentin- cement interface where more cement floated into and hardened in the undercuts. This result supported the findings of Tuntiprawon Morakot [8] and Ayad M F et al [6]. Zinc poly carboxylate cement is hydrophilic in nature and capable of wetting dentinal surface [2]. It exhibits chemical adhesion to the tooth structure through the interaction of free carboxylic acid groups with calcium. In this study, the poly carboxylate (Poly-F) cement demonstrated its greatest mean retentive value to tooth surfaces finished with regular grit diamond and lowest mean retentive value to tooth surface finished fine grit diamond (Table-XI) The possible explanation for the lowest retentive value exhibited by Poly-F to fine tooth surface could be that ploy carboxylate cement does not chemically bond to cast metal substrate. Ǿilo and Jorgensen [9] reported lower retentive value of poly carboxylate cement than zinc phosphate on rough surface; but on smooth surface the opposite relationship was reported. Omar R [10] also reported greater retentive value of poly carboxylate cement to smooth surface than that of zinc phosphate cement. Like poly carboxylate, glass ionomers are also hydrophilic in nature. The cement set by an acid-base reaction and adheres chemically to the tooth structure. Glass ionomer (GC Fuji-I) in this study, demonstrated its highest mean tensile stress to fine tooth surface and lowest mean tensile stress to coarse tooth surface. However, difference in retention in relation to regular and fine tooth surfaces was statistically not significant. Resin modified glass ionomer luting agents are combination of glass ionomer and resin chemistries, set by an acid-base reaction between aluminosilicate glass powder and an aqueous solution of poly-alkenoic acid modified with methacrylate groups, as well as chemically initiated free-radical polymerization of methacrylate units [11]. The mechanism of bonding to tooth structure is same that for conventional GICs. Resin modified glass ionomer (3M-Vitremer) in this study, exhibited its highest mean retentive value (7.0450±0.3962 MPa) with regular tooth surface group, which is the highest mean tensile stress among the luting agents used, regardless of tooth surface textures. Resin adhesive (3M-Rely-X) recorded the higher retentive values among all the luting agents used in this study regardless of the surface groups of the prepared teeth, except that 3M-vitremer in relation to regular surface group as already anticipated and GC Fuji-I in relation to fine tooth surface group. good bonding of resin adhesive cement to base metal alloy has been reported by Sule Ergin [12]

6. Conclusion

Within the limits of the study the following conclusions could be drawn:

Tooth surface textures prepared for complete cast metal crowns with diamond rotary cutting instruments of different grit sizes have a significant effect on the retentive capacities of the luting agents used in this study.

If zinc phosphate or resin adhesive luting agent is selected, the preparation surfaces should be finished with coarse grit diamond to attain the maximum retentive capacities of the luting agent.

If poly carboxylate or resin modified glass ionomer is selected, the preparation should be finished with regular grit diamond to avail the maximum retentive capacity of the luting agent.

When glass ionomer is selected, the preparation surface should be finished with fine grit diamond rotary cutting instruments to attain the maximum bond strength at the dentin-cement interface.

Resin adhesive luting agent (3M-Rely-X ARC) showed overall higher retentive capacity in this study. Hence, can be the luting agent of choice, if mandated by clinical situations. When selected, the preparation surfaces should be finished with coarse grit diamond rotary instruments.

7. Summary

Results indicated that tooth surface textures prepared for complete cast metal crowns with diamond rotary cutting instruments of different grit sizes have a significant effect on the retentive capacities of the luting agents used in this study. Resin adhesive luting agent (3M-Rely-X ARC) showed overall higher retentive capacity. Hence, can be the luting agent of choice, if mandated by clinical situations.

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