

An In Vitro Study to Evaluate the Retention of Complete Crowns Prepared with Five Different Tapers and Luted with Two Different Cements

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Abstract This study includes comparatively evaluating and drawing general conclusion about the best advisable taper and cement for maximal retention. Eighty extracted human maxillary premolar teeth with sound surfaces were selected using dial vernier caliper. Selected teeth were randomly divided into five different taper groups (0° , 3° , 6° , 9° and 12°). The crown preparations with different tapers respectively were achieved by graduated customized device. Preparations were verified with special set up. Crowns were cast with Co–Cr alloy; metal copings were luted with glass ionomer and zinc phosphate 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. Glass ionomer cemented 0° and 12° taper group showed increase in retentive strength ($p = 0.003$ hs), when compared to zinc phosphate cement. 9° and 12° group showed decreased retentive strength ($p = 0.001$ vhs) when compared with 0° taper group. No significant difference found between 0° and 3° and 6° group. The choice of cement for crowns prepared within this ideal range (0° – 6° taper) might be of limited clinical significance. 3° and 6° taper with zinc phosphate or glass ionomer cement shown to be ideal for maximum retention.

Keywords Teeth preparation · Tapers · Cements · Retentive strength

Introduction

Retention is the feature of a tooth preparation that resists dislodgement of a crown along the path of placement [1].

Taper, a main feature of the geometry of the preparation is the convergence of two opposing external walls of a tooth preparation as viewed in a given plane [2]. The extension of average lines within that plane form an angle described as the angle of convergence (total occlusal convergence) [3].

A study was conducted to evaluate the retention of complete crowns of various degree tapers, that include theoretically zero or parallel degree to clinically obtained 7° – 12° taper (14° – 24° TOC), which will be cemented with most commonly used cements in general clinical practice, i.e., zinc phosphate and glass ionomer cement, and to draw general conclusion about the best advisable taper and cement for to obtain maximal retention clinically.

Methodology

Eighty extracted human maxillary premolar teeth with buccolingual dimensions between 8 and 2 mm, mesiodistal dimensions between 6 and 10 mm with sound surfaces were selected for the study. Measurements were done using dial vernier caliper. Selected teeth were randomly divided into five groups of 16 teeth each for preparing five different tapers of 0° , 3° , 6° , 9° and 12° .

Horizontal notches were placed on the roots of each tooth for retention and then teeth were centered in

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chlorinated poly vinyl chloride (CPVC) ring using auto polymerizing acrylic resin.

Auto polymerizing acrylic resin mixed with five different acrylic colors have been used to differentiate the five different tapering groups, colors used were of pink for 0°, yellow for 3°, blue for 6°, red for 9° and clear acrylic for 12°.

A jig (CPVC ring) had been held firmly on a surveyor base and complete crown preparations were done using a high speed hand piece which was stabilized by a specially fabricated customized holding device that can be moved in horizontal plane to obtain the desired degree of taper for the preparation. Parallel sided course diamond points with a rounded tip were used to prepare axial surfaces and to establish a chamfer finish line. With the hand piece rigidly secured, the axial surface was prepared by rotating the surveyor base against the diamond bur.

Occlusal surface of the teeth were made flat, parallel to the floor and Occlusocervical dimension (h) of the teeth were standardized at 3 mm for all the specimens.

The crown preparation with different tapers 0°, 3°, 6°, 9° and 12° (Fig. 1) respectively were achieved by tilting the hand piece to their respective degree shown in the

graduated customized device by stylus which is attached to the hand piece (Fig. 2a, b).

Tapers of all the preparations were verified by measuring the Mesio distal (MD) and Bucco lingual (BL) width at cervically and occlusally using dial vernier caliper and divider and it is transferred on to the graph sheet. Cervical and occlusal markings on graph sheet were extended till the two markings meet each other and then which it is measured with protractor with special set up (Fig. 3). Any prepared tooth having an error of 0.5° taper between tooth preparation and the graph verification was excluded from the study.

Surface of the specimen was assumed as the frustum of pyramid for calculation of surface area (Figs. 4, 5). Dimensions B1, B2, L1, and L2 and h were measured to standardize the surface area of the preparations at different tapers.

Surface area was calculated as,

$$\text{Surface area} = \frac{2(L_1 + L_2)S_1}{2} + \frac{2(B_1 + B_2)S_2}{2} + L_2B_2$$

$$S_1 = h/\text{Cos } \theta = S_2$$

where, θ , taper (0°, 3°, 6°, 9° and 12°), h height (3 mm), S₁, surface area of the specimen proximally, S₂, surface area

Fig. 1 The crown preparation with different tapers 0°, 3°, 6°, 9° and 12°

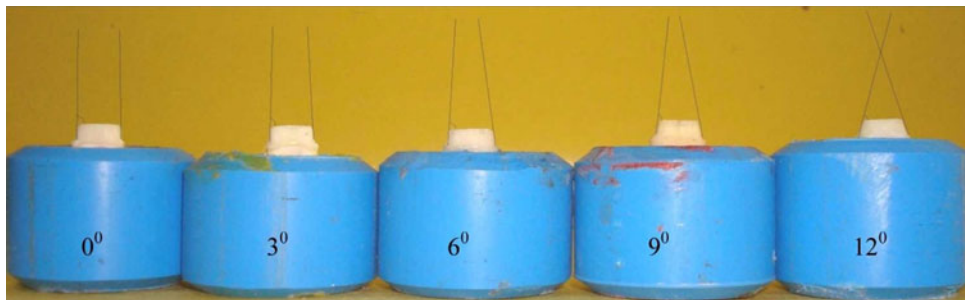


Fig. 2 Graduated customized device



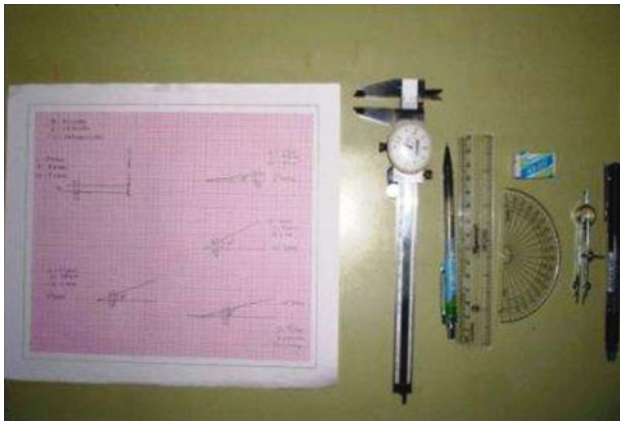


Fig. 3 Tapers of all the preparations were verified with special set up

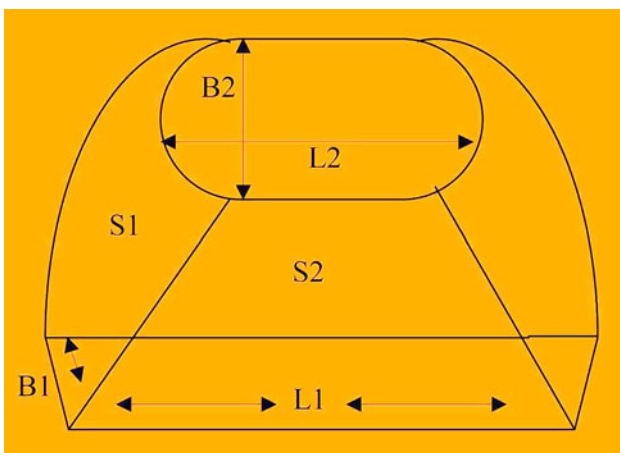


Fig. 4 Surface area of the specimen assumed as the frustum of pyramid

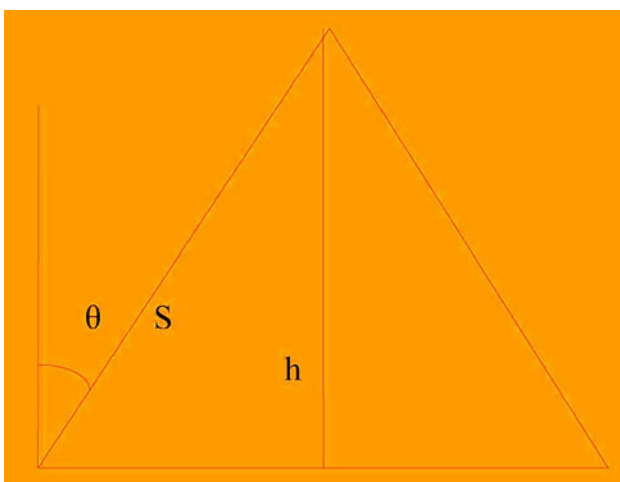


Fig. 5 Resemblance of frustum of pyramid after specimen preparation. θ = taper and h = height (3 mm) measured and applied algebraic formula to obtain the surface area (S = surface area) of each side of preparation

of the specimen buccally/lingually, B_1 , Bucco lingual dimensions of prepared premolar at the cervical region, B_2 , Bucco lingual dimensions of prepared premolar at the occlusal region, L_1 , Mesio distal dimensions of prepared premolar at the cervical region, and L_2 , Mesio distal dimensions of prepared premolar at the occlusal region.

After the teeth preparation, impressions were made with silicone material. Die preparation, wax pattern fabrication, investing and castings were done. Out of 16 samples in each group of 0° , 3° , 6° , 9° , and 12° , eight metal copings were luted with glass ionomer cement and eight with zinc phosphate cement. The luting agents were mixed according to the manufacturer’s directions. A thin film of luting agent was applied to the intaglio of the castings with a plastic instrument. The castings were seated with a firm axial movement under hand and finger pressure until the initial setting of cement. After luting, all specimens were stored in distilled water for 7 days before evaluating the retention.

Methods of Testing

An iron rod with hooks at either end was attached to the loop on the occlusal surfaces of the casting at one end and to the Instron machine at the other end (Fig. 6). The machine was switched on and the tensile load of 500 kN at cross head speed of 0.5 mm per minute was applied. The breaking load was recorded when the casting got separated from the tooth. The force at failure was recorded in kilograms. The tensile force values required to break the

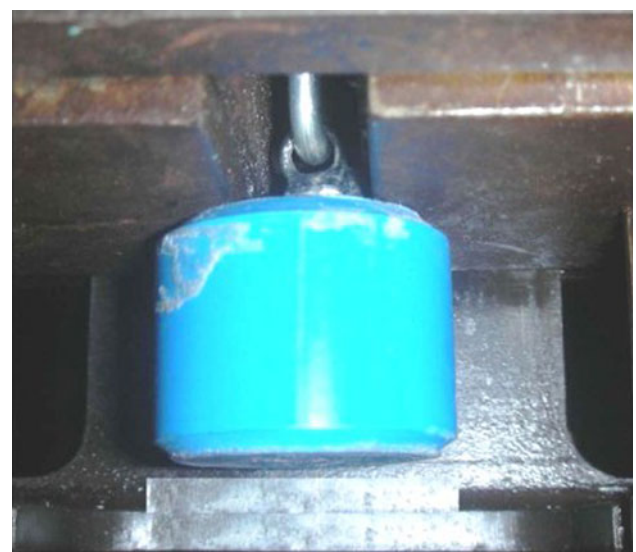


Fig. 6 A specimen positioned on to the Instron machine and connected to an iron rod with hooks attached to the loop on the occlusal surfaces of the casting at one end and to the Instron machine at the other end

specimens were calculated in Megapascals according to the following Eq. 1

$$\text{Tensile strength (MPa)} = \frac{\text{Force(kg)}}{\text{Surface area (cm}^2\text{)}} \times 0.09807 \quad (1)$$

where 0.09807 is the constant to convert the force per unit area from kg/cm² to MPa².

Results

The statistical analysis was carried out using Student's *t*-test, Fisher's test, Tukey's HSD test and Mann–Whitney *U* test.

Tables 1 and 2 shows the breaking load required to separate the castings from the tooth cemented with zinc phosphate cement and glass ionomer cement respectively. The force at failure was recorded in kilograms and converted in mega pascals. Zinc phosphate cement with 3° taper (Group Bz) and glass ionomer cement with 0° taper (Group Ag) showed the maximum breaking load (68 kg/5.10 MPa), where as zinc phosphate cement with 12° taper

and glass ionomer cement with 12° taper (Group Eg) showed minimum breaking load (21 kg/2.60 MPa).

Table 3 and Fig. 7: In 0° taper ($p = 0.003$ hs) and 12° taper group ($p = 0.016$ sig), castings cemented with glass ionomer cement showed highly significant and significant increase in retentive strength respectively when compared to zinc phosphate cement.

Table 4: In zinc phosphate (z) cement and glass ionomer (g) cement group: 0° taper (Group A) when compared with 9° (Group D) and 12° (Group E), showed very highly significant decrease in retention ($p = 0.001$ hs).

Table 5 and Fig. 8: No significant percentage reduction in retention was found between zinc phosphate cement (z) and glass ionomer cement (g) when 0° taper (Group A) was compared with 3° (Group B) and 6° (Group C). There was a very highly significant reduction in retention with 9° (Group D) and 12° (Group E).

Discussion

The form of prepared teeth and the amount of tooth structure removed are important contributors to the

Table 1 Force at failure occurred in complete crowns luted with zinc phosphate cement (z)

Sample no.	0° taper (A)		3° taper (B)		6° (C)		9° taper (D)		12° taper (E)	
	kg	MPa	kg	MPa	kg	MPa	kg	MPa	kg	MPa
1	62	5.10	50.5	4.58	40	3.99	33	3.63	20	2.42
2	63.5	5.22	61	5.55	42	4.13	35	3.87	21.5	2.67
3	62.5	5.16	52	4.70	40.5	4.19	31.5	3.41	22	2.73
4	62	5.10	51.5	4.68	42.5	4.23	31	3.40	21	2.50
5	65	5.33	53.5	4.86	66	6.61	32	3.50	25	3.01
6	67	5.55	52	4.71	61	6.19	32.5	3.52	21	2.54
7	63	5.18	68	6.17	41.5	4.03	30.5	3.36	22	2.65
8	62.5	5.15	51	4.61	40.5	4.03	45	4.92	20	2.48

Table 2 Force at failure occurred in complete crowns luted with glass ionomer cement (g)

Sample no.	0° taper (A)		3° taper (B)		6° (C)		9° taper (D)		12° taper (E)	
	kg	MPa	kg	MPa	kg	MPa	kg	MPa	kg	MPa
1	69	5.69	54.5	4.95	44.5	4.45	34.5	3.73	24.5	2.92
2	73	5.99	53.5	4.86	43	4.32	34	3.74	23	2.75
3	68	5.63	54	4.89	41.5	4.21	32	3.50	23.5	2.91
4	66.5	5.46	54.5	4.96	45	4.51	33.5	3.69	24.5	3.04
5	64.5	5.31	70	6.34	44.5	4.46	34.5	3.81	23.5	2.84
6	67.5	5.57	52.5	4.70	50.5	5.07	45	4.88	23	2.74
7	66	5.44	54	4.94	43.5	4.35	50	5.46	21	2.60
8	80	6.56	55	4.90	43.5	4.34	35	3.85	27	3.27

Table 3 Mean tensile values, standard deviations and significance values of various taper groups

Group	N	Mean	Std. deviation	t	p Value
0°					
Zinc phosphate	8	5.2238	0.15109	2.94300	0.003 hs
Glass ionomer	8	5.7063	0.40046		
3°					
Zinc phosphate	8	4.9825	0.57241	1.57800	0.115 ns
Glass ionomer	8	5.0675	0.52079		
6°					
Zinc phosphate	8	4.4638	0.26273	1.57600	0.115 ns
Glass ionomer	8	4.6750	1.07378		
p°					
Zinc phosphate	8	3.7013	0.51883	1.73400	0.083 ns
Glass ionomer	8	4.0825	0.69660		
12°					
Zinc phosphate	8	2.6250	0.18815	2.41500	0.016 sig
Glass ionomer	8	2.8838	0.20584		

Statistical analysis was carried out using Student's *t*-test

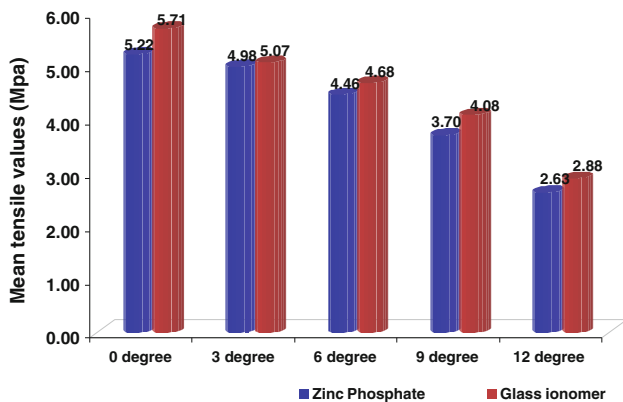


Fig. 7 Mean tensile values of zinc phosphate and glass ionomer cements at various degree tapers

mechanical, biologic and esthetic success of the overlying crown or fixed partial denture.

In this study complete crown preparations were done using a high speed hand piece which was stabilized by a specially fabricated customized holding device that can be moved in horizontal plane to obtain the desired degree of taper for the preparation. Parallel sided coarse diamond points with a rounded tip were used to prepare axial surfaces and to establish a chamfer finish line. With the hand piece rigidly secured, the axial surface was prepared by rotating the surveyor base against the diamond bur.

Previous study used a specially fabricated paralleling device to sustain the high speed hand piece and provide a standardized convergence angles, dictated by different

Table 4 Multiple comparisons of various degree tapers with in each luting agent

Group	(I) degree	(J) degree	Mean difference (I – J)	p Value	
Zinc phosphate	0°	3°	0.2412	0.928	
		6°	0.5487	0.376	
		9°	1.5225	0.001 vhs	
	3°	6°	0.3075	0.843	
		9°	1.2813	0.001 vhs	
		12°	2.5988	0.001 vhs	
	6°	9°	0.9738	0.021 sig	
		12°	2.0500	0.001 vhs	
		9°	1.0763	0.009 hs	
	Glass ionomer	0°	3°	0.6387	0.057
			6°	1.2425	0.099
			9°	1.6238	0.001 vhs
3°		6°	2.8225	0.001 vhs	
		9°	0.6037	0.081	
		12°	0.9850	0.001 vhs	
6°		9°	2.1837	0.001 vhs	
		12°	0.3813	0.458	
		9°	1.5800	0.001 vhs	
9°	12°	1.1987	0.001 vhs		

Statistical analysis was carried out using Tukey HSD test

Table 5 Mean percentage reduction in retention of 3°, 6°, 9° and 12° tapers compared with 0° taper in zinc phosphate and glass ionomer cement group

Group	N	Mean	Std. deviation	Z	p Value
0–3°					
Zinc phosphate	8	4.5439	11.38976	1.68000	0.093 ns
Glass ionomer	8	10.6112	13.23360		
0–6°					
Zinc phosphate	8	10.8631	18.06963	1.05000	0.293 ns
Glass ionomer	8	21.3945	7.67949		
0–9°					
Zinc phosphate	8	29.0557	10.54377	0.42000	0.001 vhs
Glass ionomer	8	27.9799	14.51555		
0–12°					
Zinc phosphate	8	49.7401	3.40714	0.52500	0.001 vhs
Glass ionomer	8	49.3862	3.12171		

Statistical analysis was carried out using Mann–Whitney *U* test (*Z*)

diamond bur [4], and in an another study, 80 extracted molars were prepared with a high speed hand piece secured so that a diamond bur was oriented at an angle of 10° from a vertical axis to create a convergence angle of 20°. The tooth and copper cylinder were secured vertically in

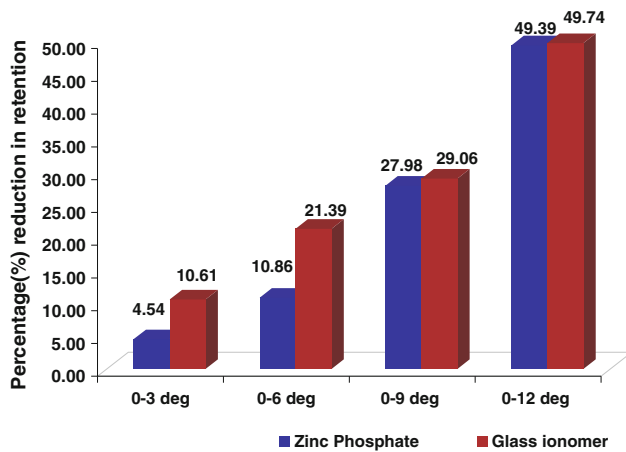


Fig. 8 Percentage reduction in retention of 3°, 6°, 9° and 12° tapers compared with 0° taper in zinc phosphate (z) and glass ionomer cement (g) groups

custom made jig held firmly in a surveyor base. A parallel sided; coarse diamond bur with a rounded tip was used to prepare axial surfaces and to establish a chamfer finish line [2, 5].

A critical factor that must be assessed for the development of a guideline for total occlusal convergence (TOC) is the actual angle formed when teeth are prepared. Many dentists have assumed that the convergence angles they produce meet the recommended 2°–6° minimal angle. However, it is important to objectively evaluate convergence angles typically established on various teeth. In this study, Tapers of all the preparations were verified by measuring the Mesio distal (MD) and Bucco lingual (BL) width at cervically and occlusally using dial vernier caliper and divider and it is transferred on to the graph sheet. Cervical and occlusal markings on graph sheet were extended till the two markings meet each other and then it is measured with protractor.

The luting ability of the cement is considered a secondary role in retention, zinc phosphate cement which achieves retention mainly from mechanical interlocking and glass ionomer cement attains retentive strength both through mechanical interlocking and physicochemical bonding.

Current study used two conventional cements i.e. zinc phosphate and glass ionomer, for to represent mechanical interlocking and physicochemical bonding. Crowns were prepared with five different tapers 0°, 3°, 6°, 9° and 12° (or 0°, 6°, 12°, 18°, 24° total occlusal convergence) and luted with two luting agents (zinc phosphate and glass ionomer).

The result of this current study showed that the glass ionomer cement measured the slight increase in retention value than that of zinc phosphate cement, but no significant increase in retention was seen.

Gordovsky et al. evaluated the retention of complete crowns by using five different methods of cementation, could not verify the claims for the superiority of the glass ionomer compared with zinc phosphate with respect to retentive strength. Both materials measured the same retentive strength, and only one specimen in each group showed unexpected results [6].

In the zinc phosphate cement (z) group, when 0° taper was compared with 3°, there was a 4.54% of reduction in retention, between 0° and 6° 10.86% of reduction, between 0° and 9° 27.98% of reduction, and between 0° and 12° 49.39% of reduction in retention.

In glass ionomer cement (g) group, when taper of 0° was compared with 3°, there was a 10.61% of reduction in retention, between 0° and 6° 21.39% of reduction, between 0° and 9° 29.06% of reduction, between 0° and 12° showed 49.74% of reduction in retention.

A research has demonstrated that retention of complete crowns cemented with conventional resinous cements diminished as the convergence angle of the tooth preparation was increased. An increase in the convergence angle from 5° to 10° has been associated with a 50% reduction in retention [4].

Within the limitations of this current study, 0°, 3° and 6° taper (6°–12° total occlusal convergence) with zinc phosphate or glass ionomer cement shown to be ideal for maximum retention.

Further investigations are needed on factors which affects retention include, different materials (metal alloys) being cemented, effect of various surface treatments on these metal alloys and other different luting agents and their film thickness.

Conclusion

- (1) The use of glass ionomer cement did not result in increased retentive strength over zinc phosphate cement in spite of the chemical bonding of glass ionomer to tooth structure.
- (2) Increasing the taper of the preparation from 0° to 3° or 6° did not affect the retention of crowns within different cement groups. Increasing the taper to 9° or 12° decreased the retention of crowns significantly.
- (3) The choice of cement for crowns prepared within this ideal range (0°–6° taper) might be of limited clinical significance.
- (4) There was almost 50% reduction in retention with 12° taper when compared with 0° taper.
- (5) 3°–6° taper (or 6°–12° total occlusal convergence) with zinc phosphate or glass ionomer cement shown to be ideal for maximum retention clinically as 0° taper is difficult to obtain clinically.

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