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THE EFFECT OF THREE ABUTMENT TAPERS ON THE RETENTION OF FULL VENEER CROWN CEMENTED WITH THREE DIFFERENT LUTING AGENTS ON MAXILLARY FIRST PREMOLAR -AN INVITRO STUDY

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ABSTRACT

Aims: To assess the effect of change in taper of the prepared abutment tooth on the retention of full veneer crown .Maxillary first premolars prepared at three different tapers namely 10 14 and 20 degrees for full veneer crown. The amount of force required for removal of the crown after cementation with zinc phosphate, polycarboxylate and glass ionomer are recorded. Statistical analysis is done to find out optimum value for abutment taper and also to find out the luting cement that provide maximum retention among the three.

Materials and Methods: In this study,18 freshly extracted maxillary first premolar teeth extracted for orthodontic treatment are used for full veneer crown preparation. A specially designed instrument is used for the standardization of crown preparation. .All the 18 samples were cemented with zinc phosphate cement and recorded the force required for crown removal. The crowns are cleaned and dried and test is repeated with polycarboxylate and glass ionomer cement. Statistical analysis was done with ANOVA.

Results: The crown cemented on abutment with 140 taper required maximum force for crown removal irrespective of type of the cementing medium employed. Among the three different luting cements employed, the crown cemented with polycarboxylate required maximum force for debonding.

KEYWORDS : Abutment taper, luting cement, retention, full veneer crown

INTRODUCTION

Definite treatment for most cases of compromised natural dentition requires treatment with crown, fixed partial denture or implant supported prosthesis. The treatment of choice is fixed partial denture for majority of patients. The factors that are to be considered during the tooth preparations in fixed partial denture treatment are biological, mechanical and esthetic factors. Among the mechanical factors, the retention of the full veneer crown on the abutment tooth is the most important one. Loss of retention of crowns is one of the major factors leading to the failure of fixed partial denture. Retention depends on the degree of convergence of the opposing axial walls, the surface area and the factors related to the casting and cementing media[1]. Research has demonstrated that the retention of complete cast crowns cemented with conventional cements diminishes as the convergence angle of the tooth preparation is elevated.

Absolute parallel walls provide maximum retention. But it is practically difficult to prepare absolute parallel walls in the oral cavity.It should be prepared with minor degree of convergence to expose the prepared surface ,avoid undercuts and to have an accurate and thorough construction process and compensate inaccuracies.

Ward[2] was the first to recommend a convergence angle of 3 to 12^0. In subsequent years, the so-called convergence angle has varied between 3 to 5^0 and 10 to 14^0 [3,4]. Wilson Jr and Chan [5] proposed a 6 to 12 range for the convergence angle since it is practically viable and facilitates laboratory work in association with a better retention between the crown and tooth. Goodcre et al[6] reviewed the papers of the last 50 years and concluded that the convergence angles of 10 to 20^0 yield the best clinical results. Chandra Shekhar et al[7] evaluated 80 crowns of the upper premolar teeth bonded with glassionomer and zinc phosphate cements. They reported that by increasing the angle of convergence from 0 to 6 or 12^0, no major change was observed in crown retention. They also concluded that decreasing this angle from 18 to 24^0 reduced retention significantly. It should also be noted that from 24^0 upward, retention drops by 50%.

The present study was conducted to find out the effect of abutment taper on the retention of full veneer crown on maxillary first premolar. The study was conducted using 3 abutment tapers 10 14 and 20 degrees .The force required for crown removal is recorded when fixed with 3 different cements namely .zinc phosphate polycarboxylate and glass ionomer. Tensile force needed for crown removal is calculated and statistically analysed.

METHODOLOGY

Eighteen sound human maxillary first premolar teeth extracted for orthodontic treatment purpose were collected and stored in distilled water at room temperature till the study was started. All the selected teeth fulfilled Major M Ash[8] criteria for tooth carving.A platform was designed so that it will fit accurately the tilt top of the cast holder of a Ney surveyor. The platform contained a circular slot on which the bottom of a polyvinyl chloride container fitted accurately. The tilt top was made parallel to the horizontal surveyor base and the locking screw was lightened. The polyvinylchloride cylinder containing mould for mounting the specimen was placed on the platform. It was made sure that the bottom of the cylinder was fitting snuggly to the circle on the platform. Autopolymerizing resin was mixed and placed in the container in a semi fluid consistency. The specimen was embedded in autopolymerizing resin (one per mould) vertically in the centre of the mould(Figure 1). The anlyzing rod suspended from the tool holder was used as a guide to position the tooth specimen so that the long axis of the specimen was parallel to the analyzing rod. The teeth were placed in such a way that the cementoenamel junction was about 1-2mm above the level of acrylic and held in place till the polymerization was complete. The mounted teeth were stored in an atmosphere of 100% humidity except at the time of embedding, tooth preparation, impression, cementation and removal of the crown.

A Ney surveryor was modified to prepare the mounted teeth to the desired taper (Figure 2). An angulated shaft was attached to the

vertical spindle.The tool holder locking nut was used to lock the shaft in position. A high speed hand piece was attached to the other end of the shaft. The angulation of the straight fissure bur fitted on the hand piece is adjusted by using a replaceable angle measuring device. By using this device the angulation of the bur with the vertical was adjusted according to the taper required for tooth preparation. The device could be placed accurately on the cast holder with the help of the platform placed on the cast holder.

The 18 samples were randomly assigned into three groups each containing six samples. The groups were named A, B and Cand used to study the effect of abutment taper on the retention of crowns cemented with zinc phosphate, polycarboxylate and glass ionomer luting cements. The teeth were prepared in three different tapers.

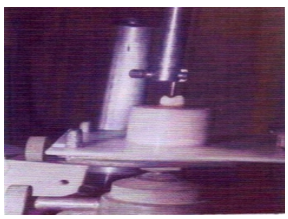


Fig. 1: Embedding the specimen in auto

Fig.2: Modified Ney surveyor used in the Polymerizing resin study for preparing the embedded teeth

Fig. 3: The prepared tooth, putty wash,

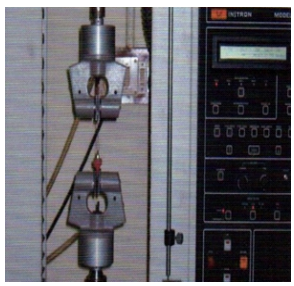


Fig. 4: The procedure of debonding impression die and crown fixed crown in the Instron machine on the prepared tooth

Group A — 100° taper (50 inclination per wall)
Group B — 140 taper (70 inclination per wall)
Group C - 200 taper (100 inclination per wall)

The occlusal surface of the specimen was reduced in such a way that the occlusal surface was flat and the occluso-cervical dimension is 4mm. The angulation of the straight fissure bur with the vertical was kept in the desired angulation by using the angle measuring device. The inclination per wall needed in the crown preparation was adjusted as the angulation of the straight fissure bur with the vertical. The device was then replaced by the polyvinyl chloride container with the sample and crown preparation was done by moving the cast holder. All teeth were prepared with shoulder finish line. A new rotary instrument was used for each tooth and continuous water jet was directed at the rotary instrument. After crown prepartion each specimen was examined under a microscope (Mitutoyo Inspection Microscope) and confirmed that the inclination of each wall was the same as that set in the angle measuring device.

After the tooth preparation, the surface area of each specimen was calculated. Specimen surface area (At) was calculated using the formula for a truncated cone (Ac) to which the area of the flat occlusal surface (Ao) was added[9]

$At = Ac + A^{o}$

$Ac = \pi L(r_1 + r_2)$

Ac= Convergent preparation surface area
L= vertical height of the preparation
r_1= Radius of cervical diameter
r_2= Radius of occlusal diameter

$Ao = \pi(r_2)^2$

Ao Area of flat occlusal prepared surface

Diameter of the prepared tooth was measured accurately in millimeters by using Iwans decimal caliper. The average diameter was calculated by measuring the mesiodistal and buccolingual diameters. From this average radius was calculated.

A special tray was fabricated using autopolyrnerizing resin after adapting two layers of modeling wax over the prepared tooth surface and to the cylindrical part of the acrylic block holding the specimen. After the polymerization was over, the wax spacer was removed and a putty wash impression was taken by using ZetaplusSoft and Oranwash L .Die was prepared by using Type IV Die stone (DenfloDie stone,Prevest Denpro Ltd). After the die stone was set two coats of die spacer (Die and Cement spacer, Good Fit system) was applied on the surface of the die.

A wax pattern was prepared over the die using inlay wax. An inverted 'U' shaped loop was placed on the occlusal surface of the wax pattern to serve initially as a sprue and later as an attachment to the testing machine. The highest point of the loop was placed at equal distances from the centre of the distal and mesial surfaces of the preparation to help in centering the load over the casting during testing. The patterns were removed from the die and invested in phosphate bonded investment and casting was done in Century D casting machine.

The castings were air abraded with 50 micrometer aluminum oxide powder, tried on the prepared teeth and adjusted to proper fit. All the 18 samples (Group A containing 6 samples, Group B containing 6 samples and Group C containing 6 samples) were cemented by using zinc phosphate luting cement (Phosphate Cement). The cement was mixed according to the recommended power liquid ratio of the manufacturer. A thin layer of cement was applied to the inside of the crown and the crown was immediately cemented on the tooth using firm hand pressure. The excess cement was removed after 10 minutes. After storage for 24 hours in distilled water at room temperature, specimens were mounted in a universal testing machine (Instron- 1011) in a path parallel to the axis of withdrawal(Figure 4). A cross head speed of 1 mm/minute was applied in tension to each casting until the cement failed. The load at failure was noted in Newtons (N).

After the test was over the crowns and teeth were thoroughly cleaned teeth. The gross deposits of cement were removed with a spoon excavator. Every attempt was made to preserve the morphology of the prepared teeth by engaging only the cement with excavator during its removal. After initial removal of these deposits, the teeth were cleaned. A rubber prophylaxis cup and a mixture of flour or pumice and water were used to clean the samples. Each tooth was cleaned in this manner by using ligt, intermittent pressure. The crowns were also cleaned and recemented using polycarboxylate cement (poly-F) and stored under the same conditions. After 24 hours, tensile-testing procedures were repeated.

After the test procedure was over, the specimens were again cleaned and recemented by using glass ionomer cement (GCFuji I). the test procedure was repeated and the values were recorded.
In each test procedure the tensile stress was calculated by dividing the debonding force (Newton) by the surface area of the corresponding crown in millimeter.

Newton
Mpa =
mm^2

. Statistical analysis was done by the analysis of variance (ANOVA). Two way ANOVA was used to find out whether there was any significant difference when the two variables, namely taper and cement, were altered. One way ANOVA was used to find out whether there was any significant difference when three different tapers were employed.

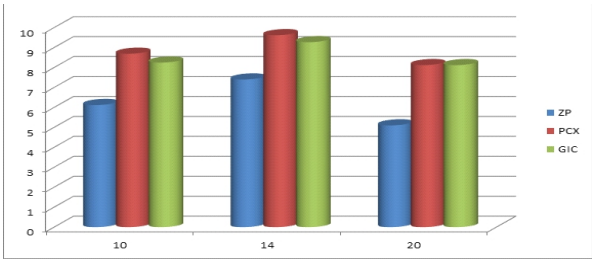
Table 1
Comparison of tensile load required for crown debonding when three different abutment tapers employed and fixed with three different luting cements

Taper of prepared tooth	Zinc phosphate	Polycarboxylate	Glassionomer
100 Taper	6.25	8.20	7.90
	5.78	9.00	8.20
	6.36	9.01	8.40
	6.25	8.60	8.10
	5.80	8.80	8.60
	6.25	8.50	8.30
140Taper	7.10	9.40	8.40
	7.70	9.80	9.20
	7.30	9.90	9.60
	7.89	9.60	9.30
	7.20	9.30	9.50
	7.20	9.70	9.60
140Taper	5.29	7.9	7.8
	5.00	8.30	8.10
	4.92	8.10	7.90
	5.28	7.80	8.20
	5.11	8.40	8.40
	5.00	8.20	8.30

Table 2: Two way ANOVA comparing the abutment taper and cementing media

Effective retention	Sum of squares	Degree of freedom	Mean sum of squares	F ratio	P -value
Combined	99.128	4	24.782	311.042	P < 0.001
Cements	73.876	2	36.938	463.619	P < 0.001
Taper	25.251	2	12.626	158.466	P < 0.001
2way interaction	2.298	4	0.574	7.210	P < 0.001
Model	101.425	8	12.678	159.126	P < 0.001
Residual	3.585	45	7.96	-	-
Total	105.011	53	1.981	-	-

Diagrammatic representation of Mean values of the retention of full veneer crowns on teeth prepared with three different tapers and cemented with three different cements



RESULTS

Results showed that full veneer crowns cemented on maxillary first premolar with 14^0 taper gave the highest tensile load values at the time of crown separation .The test is done after cementing with three different luting cements .In all the three situations 14^0 abutment taper gave maximum retention for the full veneer crown. Among the three luting cements employed the crowns fixed with polycarboxylate cement gave highest tensile load values on separation. When the values are analysed statistically by one way ANOVA taking one variable namely; abutment taper, the P value obtained is less than 0.01 showing that there is a significance in retention when there is difference in abutment taper. When statistical analysis is done by taking consideration of two variables namely abutment taper and luting cements (two way ANOVA) P value obtained is less than 0.001 indicating that there is highly significant difference in retention values of crowns when both the parameters are altered.

DISCUSSION

The loss of retention of cemented crowns is the major cause of failure in fixed partial denture service. Retention is that quality inherent in a prosthesis that resists the forces of gravity, the adhesiveness of foods and the forces associated with the opening of jaws[10]. This property of the restoration prevents the removal of that restoration along the path of insertion or long axis of tooth preparation. Tensile stress is the internal induced force that resists the elongation of a material in a direction parallel to the direction of stress. Even though a number of complex stresses are acting on the restoration during mastication, the major stress is the one that tries to pull the restoration away from the tooth and this is called the tensile stress.

The major factors influencing the retention of full veneer crowns were shown to be the geometric relationship of the prepared tooth surface and the mechanical properties of the luting cement. The geometric configuration of the tooth preparation must place the luting agent in compression to provide the necessary retention. The cements should prevent the loosening of the restoration by sticky food. The retention provided by the compression of two opposing dentinal walls is called tensofrictional resistance. Excessive taper provides insufficient retention and resistance and often compromise pulpal health. The angle of convergence of the prepared tooth or the taper of a crown is the angle formed between two opposing walls of the preparation. The relationship of the one wall of the preparation to the long axis of that preparation is called the inclination of that wall. Previous studies have demonstrated that the retention of complete cast crowns cemented with conventional cements diminishes as the convergence angle of the tooth preparation is elevated. Maximum retention is obtained when the two opposing walls are parallel. The position in the oral cavity and the morphology of the teeth create problems in producing absolutely parallel walls without creating undercuts. The preparation walls should be tapered to visualize preparation walls, prevent undercuts, and compensate for inaccuracies in the fabrication process and to permit more nearly complete seating of restorations during cementation. Studies by Mack[11] had shown that a minimum taper of 12^0 is necessary just to ensure the absence of undercuts. Dodge et al[12]had demonstrated a total convergence of $16^0$for achieving the adequate retention. According to Schillingburg[13]the optimum over all taper needed for a maxillary premolar is 14^0.Wiscott H W et al[14]studied the relationship between abutment taper and resistance of cemented crown to dynamic loading. They investigated the relationship between abutment total occlusal convergence angle (taper)and the resistance of cemented crown subjected to dynamic loading. Crown were fixed to abutment analog using zinc oxide eugenol, incphoshate glass ionomer or rein composite cement. The relationship between convergence angle and resistance to removal was approximately linear for all the cements tested. Smith DC [15] listed the essential properties of ideal luting agent. According to him it should provide a durable bond between dissimilar materials ,posses favourable compressive and tensile strength and should have sufficient fracture toughness to prevent dislodgement as a result of interfacial or cohesive failures. It should also be able to wet the tooth and the restoration, should exhibit adequate film thickness and viscosity to ensure complete casting. The luting agent should be resistant to disintegration in the oral cavity, should be tissue compatible and should demonstrate adequate working and setting time. Henry O Gold[16] devised an

instrument for preparing the abutment teeth to the desired taper. It consisted of a Ney surveyor with machinist's protractor affixed and adapted for the measurement of degree of taper of prepared teeth. Felton Kanoy and White[17] conducted a study and found out whether the retention of artificial crown varied with the geometric relationship of the prepared tooth surface. They prepared the abutment teeth to the desired taper by attaching a high speed hand piece to a surveyor with an aluminium jig.

In the present study the hypothesis tested was that the taper of the abutment tooth had no effect on the retention of full veneer crowns. This was the null hypothesis. The alternate hypothesis was that the taper of the abutment tooth had an effect on the retention of full veneer crowns. In order to test the hypothesis, three convergence angles were selected and these three convergence angles were tested under three different conditions, cementing by three different cements.

The three convergence angles selected for the study were 10^{o}, 14^{o}, 20^{o}. The three luting cements used were zinc phosphate, zinc polycarboxylate and glass ionomer.

Zinc phosphate cement has been the most widely used luting agent for more than a century. It consists of zinc oxide and magnesium oxide and the liquid contain phosphoric acid, water aluminium phosphate and zinc phosphate. The primary bonding between the prepared tooth and the crown occurs by mechanical interlocking at the interfaces. Zinc polycarboxylate cement was the first cement system that developed an adhesive bond to tooth structure. The powder contains zinc zinc oxide with some magnesium oxide. The liquid is an aqueous solution of polyacrylic acid or a copolymer of acrylic acid with other unsaturated carboxylic acids such as itaconic acid. The cement bonds chemically to the tooth structure. The polyacrylic acid reacts via the carboxyl groups with calcium of hydroxyapatite. Type I glass ionomer cements are designed for cementation of castings. It consists of a powder liquid system. The powder is an acid soluble calcium fluoraolumino silicate glass. The liquid is an aqueous solution of polyacrylic acid. It binds to tooth structure by the chelation of carboxyl groups of the polyacids with the calcium on the apatite of the enamel and dentin.

In the present study, when zinc phosphate was used to fix the crown, the tooth prepared with 14^{o} taper gave the maximum retention value for the crowns. When the crowns were fixed by using polycarboxylate cement and the retention was checked, crowns fixed on teeth prepared with 14^{o} taper gave the maximum retention values. When the retention was analyzed after fixing with glass ionomer cement, 14^{o} taper gave the maximum retention values.

From the results of the study it can be concluded that the null hypothesis is rejected .The alternate hypothesis was that the convergence angle of the preparation or the abutment taper has an effect on crown retention. The alternate hypothesis is correct and among the various tapers 14^{o} is ideal for maxillary first premolar to receive a full veneer crown to obtain maximum crown retention.

CONCLUSION

Different abutment tapers gave different values for the retention of full veneer crowns. The optimum retention for full veneer crown on maxillary first premolar is 14^{o}. The type of cementing medium had an effect on the retention of full veneer crowns and among the three cements used in the present study gave significantly different retention values. The full veneer crowns fixed with polycarboxylate luting cement on maxillary first premolar with 14^{o} taper gave maximum retention.

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