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A Comparative Evaluation Of The Effect Of Various Finish Lines On The Marginal Seal And Occlusal Discrepancy Of Cast Full Crowns After Cementation - An Invitro Study.

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Abstract

Purpose of study: To compare the marginal sealing ability of the various configurations of the finish lines and its effect on the occlusal seat of the full crowns after cementation.

Material and Methods: Six stainless steel metal dies were machined with finish line configuration: Ninety degree shoulder, Rounded shoulder, 45 degree sloped shoulder, Chamfer, Long chamfer and Feather edge. Five metal crowns were fabricated on each metal die. These crowns were cemented on duplicated resin dies and sectioned longitudinally. The sectioned halves were focused under stereomicroscope and the cement thickness was measured. Data obtained was statistically analysed using ‘One way variance ANOVA test’ and ‘Students unpaired t-test’.

Results: The results of ANOVA test for occlusal seat (‘F’ value 932.1 and’P’ value < 0.0001) and marginal seal (‘F’ value 556.8 and ‘P’< 0.0001) were statistically significant. Feather edge, long chamfer and chamfer were superior in sealing the margins (32µ, 51µ and 107µ) followed by shoulder preparations. 90-degree shoulder (130µ), had best occlusal seat followed by 90-degree shoulder with 30-degree bevel, 45-degree shoulder, Chamfer long Chamfer, and feather edge (164µ, 164.4µ, 224µ, and 281µ). Individual unpaired t-test revealed that results where significant for all groups (P value > 0.05).

Conclusion: Among all the finish lines, feather edge margin has best marginal seal but poor occlusal seat and 90-degree shoulder margin has best occlusal seat but poor marginal seal. Chamfer margin over all shows better marginal seal and occlusal seat.

Keywords: marginal seal, occlusal seat, finish lines, cement thickness, cement dissolution

Introduction

Fixed Prosthodontics, as a specialty of Prosthetic dentistry is a vital part of today’s modern dentistry which is routinely practiced by both general practitioner and Prosthodontist. The scope of Fixed Prosthodontic treatment can range from the restoration of a single tooth to the rehabilitation of the entire occlusion[1].

It is humbling to realize that fixed dental prostheses were being placed long before the birth of Christ. From the time when the first fixed bridge work was constructed in 7th century B.C by the Phoenicians, fixed partial denture have developed in a drastic manner. The successful tooth preparation and subsequent restoration depends upon the biologic, mechanical and esthetic factors[2]. Among various factors which contribute to success of fixed dental prosthesis, accurate marginal seal and occlusal seat of restoration are equally important in determining the long term clinical success of the cast restorations.

Factors such as the materials used and the esthetic requirement of the restoration determine the type of finish line to be made. The margin configurations commonly used by operator are Shoulder, Shoulder with bevel, Chamfer, Long chamfer and Feather edge. There is always some discrepancy between the margins of the preparation and the restoration. The discrepancy at right angle to the two opposing surfaces is termed as the 'horizontal discrepancy' or 'marginal adaptation'. Whereas, the discrepancy at the external margin has been described as 'vertical discrepancy' or 'marginal opening measured'. The least confusing terminology is "seating" to describe the vertical discrepancy at the external margin, and "sealing" to describe the horizontal discrepancy observed at right angles to the two opposing surfaces[3].

Poor marginal adaptation increases the potential for microleakage and plaque retention which in turn raises the risk of recurrent caries and periodontal disease. A luting agent is used to fill this space and provides both marginal seal and frictional retention for the casting. Kashani H, khera SC, Gulker IA in 1981[4] reported that poor margins increase cement dissolution and there should be a band of close adaptation (about 1mm wide), at the preparation margin to prevent the dissolution of the luting agent.

Another problem encountered during cementation of the crowns is that the cementing medium may prevent the complete seating of the crown, positioning it in hyperocclusion and resulting in inadequately sealed margins. Factors that affect the film thickness of cement under casting include cementing force, duration of force, type of cement, viscosity of cement mix, convergence angle, preparation dimension, hydrostatic pressure within crown and the type of finish line used for tooth preparation[5,6]. Different finish lines have varying effects on the escape of cement during the cementation process. Schillingburg[1]and Preston[7] recommended the shoulder with bevel as the best type of finish line for a cast restoration. Rosner[8] reasoned that bevelled finish line will fit better than a shoulder. Several authors[9-14] have investigated the crown adaptation and influence of cementation variables, without reference to the internal fit prior to the cementation and observed that these crowns do not seat and recommended various methods to overcome the hydrodynamic forces. Cho LR, Choi JM, Yi YJ and Park CJ[15] compared the vertical marginal accuracy of shoulder, round shoulder and chamfer finish line preparation and concluded that round shoulder finish line has better occlusal seat and seal. However, other authors have reported that the finish line had no influence on the marginal adaptation of castings[16,17].

There is limited and contradictory theoretical, laboratory and clinical evidence available about which finish line offers the greatest advantage. Hence, an in-vitro study was planned to compare and evaluate the influence of various finish line configurations on the marginal seal and occlusal seat of full cast crowns after cementation.

Materials and Methods

A. Machining of Metal Dies

To simulate a tooth preparation, six stainless steel (SUS303) metal dies were machined on Computerized Numerical Control (CNC) machine (Markon, India) having cervical diameter of 10mm and cervico-occlusal height 6mm. The taper of axial walls was 5-degrees with convergence angle of 10-degrees. The occlusal surface was kept flat with a small circular dimple of 1mm for reorientation of the wax pattern and metal copings. Six different finish line configurations: 90-degree shoulder (Group A), 45-degree shoulder (Group B), 90-degree shoulder with 30-degree bevel (Group C), chamfer (Group D), long chamfer (Group E) and feather edge (Group F) were prepared on the metal dies. For preparation of shoulder finish lines marginal width was kept 1 millimetre. Group A- shoulder was angled at 90-degree. Group B -shoulder was angled at 45-degree to the long axis of the prepared die. Group C- 90-degree shoulder with 30-degree bevel. Group D- Chamfer had a width of 1mm. Group E- long chamfer having a larger arc of sphere. Group F - feather edge margin had no marginal width and 5- degree taper from the margin (Fig.1a&b).

B. Fabrication of the Metal Crowns

Five cast full crowns were fabricated on each metal die and one extra crown was fabricated on metal die of Group C for control group. The die lubricant (Picosep, Renfert GmbH, Germany) was applied to the surface of the metal dies. The wax patterns of uniform thickness of 1mm were made in blue inlay casting wax (S.U. Modelling wax yellow and blue Schuler Dental, Germany) directly on the metal dies using the dip wax technique (Fig.2). These wax patterns were attached to crucible former by sprue wax (S.U. Casting Sprues; 4 mm, Schuler, Germany). It was then invested using the mould former of the ringless casting system and phosphate bonded investment material (Deguvest, Dentsply International Company, Germany) mixed in a vaccum –mixing machine (Vacu_stir, Puneet industries, India). A ratio of 20:4 of special liquid to distilled water was used for investing. After setting, it was placed in the burnout furnace (Quartz_Fur, Puneet industries, India) and after burn out mould was transferred to the induction casting machine (Centrifugal Bego, Germany) and casting was done using nickel chromium alloy (NDN, Dental Alloy for Ceramics, Premier Dental International,Germany). The castings were retrieved from the mould and deinvested thoroughly by airborn- particle abrasion using 50 micron. In this way total 30 crowns and one extra crown for control group were fabricated. On the outer surface of all crowns a vertical groove was marked with the help of round bur, which aided in indexing and repositioning.

C. Fabrication of Resin Dies

To overcome the casting variables, the intaglio surfaces of the casted crowns were lubricated with a drop of silicon oil. A measured volume of methyl methacrylate resin (Trevalon RR, autopolymerising acrylic resin) was vibrated into the mould of putty impression material (Zetaplus, C-silicone impression material, Zhermack company) around the castings to make direct acrylic dies. Extra metal crown of control group was filled with methyl methacrylate resin without applying silicon oil. Twenty four hours later these dies were indexed to aid proper repositioning during cementation by drawing a vertical line on the acrylic die using a permanent marking pen below the vertical groove of the crown (Fig.3). The acrylic resin dies were then retrieved from the crowns, which were the exact replica of the intaglio surface of the crowns and the finish lines.

D. Cementation of Metal Crowns

The crowns were cleaned with alcohol to remove traces of silicon oil and dried. Zinc phosphate luting cement (DeTrey, Dentsply; Germany) was used for the cementation (Powder:Liquid ratio-1.5:1 by weight). Standardization of successive mixes was assured by proportioning the two components of the cement on a precision balance (Explorer, Ohaus corporation, USA) with an accuracy of 0.001grams. After proper mixing, luting agent was applied to the internal surface of the crowns and seated on acrylic die with a firm axial movement under hand and finger pressure. Then specimens were placed vertically under Universal testing machine (EPOCH company, Banglore, India) to apply a constant load of five kilograms for five minutes. To simulate clinical procedure of dynamic loading, an orangewood stick was placed in between the crown and the compression head of the testing machine (Fig.4).

E. Sectioning the Embedded Crown-die Assembly

After 24 hours, the cemented crown and acrylic die assembly were embedded in translucent (clear) acrylic resin (DPI-RR, India) to hold the assembly together while sectioning (Fig.5).Twenty four hours later, all the samples were sectioned longitudinally with an ultra thin rotary silicon carbide disc (rotation 3350 r.p.m). Water with added detergent was used as a coolant lubricant (Fig.6). The cut surfaces were then polished and buffed on Lapping machine (Lapping machine- surface polisher, Pune, India).

F. Measurement of Cement Thickness Under Crown

The sectioned halves of crown-die assemblies were focused under a stereomicroscope (Fig.7) at 10X magnification and the cement spaces were measured to the nearest micron with an eyepiece micrometer mounted on reflecting microscope. The cement space was measured at four points, two points on the occlusal surface and one at each margin at cervical level (Fig.8) and average was taken. The cement thickness at the occlusal surface shows the occlusal seat and the cement thickness at the marginal area represents the marginal sealing ability afforded by the respective finish line design (Fig.9a&b). The readings, thus obtained, were subjected to statistical analysis using one-way ANOVA and Students unpaired t-test.

Results

A total of thirty (30) samples comprising the 6 Groups (Group A to Group F) were tested. The results for cement thickness were observed in microns (Table 1)**.** This data has been summarized in 3 bar diagrams. (Graph 1, 2 & 3). The data in Table I and Graph 1 shows that feather edge preparation had the best marginal seal having cement thickness of 32µ at margin followed by long chamfer (51µ), Chamfer (107µ), 90-degree shoulder (123µ), 90-degree shoulder with 30-degree bevel (132µ) and 45-degree shoulder (152.4µ). Table I and Graph 2 show the least measurement of cement thickness at occlusal surface for 90-degree shoulder (130µ) followed by 90-degree shoulder with 30-degree bevel (152.4µ), 45-degree shoulder (164.4µ), Chamfer (224µ) and long Chamfer (281µ). The feather edge margin had worst occlusal seat (300µ).

The statistical analysis was performed using statistical software (Graphpad prism 5). The data was interpreted at a confidence interval of 95%. The mean and standard deviations were calculated for statistical analysis of all the 6 groups (Table 2 & 3 and Graph no.3). One way analysis of variance (ANOVA) test was used for evaluating the mean differences among all the 6 groups for occlusal seat (Table 4a). The 'F' value obtained was 932.1 and at 95% confidence interval the 'P' value was less than 0.0001. This analysis revealed that results were statistically significant. Results of ANOVA test for marginal seal (Table 4b) were also significant having 'F' value 556.8 and 'P' value less than 0.0001. The individual unpaired t-test was applied to test the significance of difference between the mean values for different groups which shows the results were significant for all groups (P value < 0.05) except between group B and group C, where the difference between the mean values of occlusal seat was statistically insignificant(P value> 0.05).

Discussion

Standardized metal dies of the volumetric size of an average molar were used to control the variables of preparation dimensions, degree of axial wall taper and the finish line dimensions that have also been frequently used in previous studies.[9,11,12,13]Various authors recommend a convergence angle of 4 to 14-degrees.[1,2] For these reasons, the dies were machined to a convergence angle of 10-degrees with a five degree taper on each axial wall[14].

The wax patterns of uniform thickness of 1mm were made directly on the metal dies using the dip wax technique because it has been shown by Fusayama T, Ide K, Kurosu A and Hodosa H[10] that the degree of adaptation or misfit of the crown that has been waxed onto a metal die is less than for a crown waxed on a stone die. Nickel Chrome (Ni-Cr) alloy was used for the fabrication of crowns as it offered enhanced compressive strength and resistance to deformation during cementation and sectioning, especially at the thin margins of feather edged preparations.

Mclean JW and Von Fraunhofer[18] found that gaps always exist between the metal crown and the metal die even though there may be contact points in certain areas. To eliminate all casting errors and measure only the marginal opening due to the marginal configuration, the acrylic resin dies were made directly within the castings. It is accepted that methyl methacrylate resin shrinks on polymerization but this factor did not affect the present study. Shrinkage did occur, but it was limited to the open end of the boxed castings, thus causing meniscus formation[13.] Control group was established by embedding acrylic die-metal crown assembly in clear acrylic resin without cementation, after sectioning microscopic examination revealed no shrinkage spaces between the die and the internal surface of the crown (Fig.10). Internal relief was not given for two reasons, first, to eliminate the influence of cement space on the seating of the crown and secondly, to avoid the computation of the variable as a result of inability to standardize the dimension of the acquired relief space[19].

Zinc phosphate luting cement was used for the cementation of the cast crowns on acrylic dies as the margins of composite resin and zinc phosphate cements remains intact while those of glass ionomer cement substantially dissolve from the margins[20]. The specimens were placed vertically under Universal Testing Machine (UTM) to apply a constant load of five kilograms for five minutes. To simulate clinical procedure of dynamic loading and to distribute cementation pressure more evenly an orangewood stick was placed in between the crown and the compression head of the testing machine[21]. The cemented crown and die assembly were embedded in translucent (clear) acrylic resin to hold the assembly together during sectioning. After 24 hours, all the samples were sectioned longitudinally with an ultra thin rotary silicon carbide disc.

The sectioned halves were then focused under a stereomicroscope at 10X magnification and the cement spaces were measured to the nearest micron. The cement space was measured at 4 points, two points on the occlusal surface and one at each cervical margin of either side[14]. The measurement of cement thickness at the occlusal surface shows the occlusal discrepancy and the cement thickness at the marginal area represents the marginal sealing ability possessed by different finish line design.

It was observed that the feather edge, long chamfer and chamfer were superior in sealing the margins with cement thickness 32µ, 51µ and 107µ respectively followed by shoulder preparations i.e. 90-degree shoulder, 90-degree shoulder with 30-degree bevel and 45-degree shoulder with cement spaces of 130µ, 169µ, 169.4µ respectively. The feather edged margin had the best marginal seal and 45-degree shoulder showpoor seal. These findings regarding marginal seal are in accordance with the studies conducted by Tjan AHL[19], Kay WG et al[22] and Muddugangadhar BC, Garg A, Mawani D and Das A[23] and Tantrey MA[24]. However Amini and Abaslo[25], Shillinburg et al[26], andVaidya S, Parkash H, Bhargava A and Gupta S[27]in their study found that the three margins-chamfer, shoulder and shoulder with bevel have insignificant difference in the marginal fit, althoughbased on the mean values, shoulder with bevel margin showed the best marginal fit.

Based on geometric design, the 90-degree shoulder would be expected to have the greatest opening at the margins but 45-degree shoulder with reading of 169.4µ had the poor seal among all the margin designs, because the decrease in cement line depends on the inclination of the bevel at the margin. According to Pascoe DF[28] marginal design with bevel more than 60-degree substantially decreased the closing angle between the tooth preparation and the restoration. According to the sliding joint principle, a parallel bevel minimizes the thickness of cement between the internal surface of the casting and the bevel on the tooth. Hence, the exposed cement of the shoulderless crown remains minimal regardless of the magnitude of lack of seating. This finding was also observed by Fusayama T, Ide K and Hosoda H [10].

The lowest value of cement thickness at the occlusal surface was obtained with 90-degree shoulder finish line configuration. Cho LR, Choi JM, Yi YJ and Park CJ[15]with similar resultsexplained that the better seat of shoulder finish line preparation was because it allowed the cement to escape more easily. The occlusal cement thickness was maximum with the feather edged preparation, 300µ followed by long chamfer and chamfer marginal design. These margins did not allow the castings to seat completely because these margins seal earlier and start the filtration process sooner. They substantially decrease the closing angle between the tooth preparation and restoration and do not allow the cement to escape easily[4]. Long chamfer and feather edge marginal designs magnify the difference between seating and sealing gaps. The seating and sealing discrepancies are equal in horizontal designs such as shoulders. The width of the exposed cement line of a crown cemented on a preparation with a cervical shoulder is directly proportional to magnitude of lack of seating of the crown. This was in support of the views given by Grajower R and Lewinstein I[29]. The mean marginal discrepancies of shoulder, chamfer, long chamfer and feather edge margins in this study were within the clinically acceptable standard (120 µm) according to McLean and Fraunhofer's study[18].Thus, the findings of sthis study support those of the previous studies and the predictions based on the geometry of the preparations.

A limitation of this study was that the metal crowns were formed from standard dies. However, in clinical practice tooth preparations are more complicated than the standardized dies as natural teeth have varying axial heights and are prepared to different degree of taper.

Conclusion

Within the limitations of the present study, it was found that the degree of marginal seal and occlusal seat of the crowns was significantly affected by the different finish line designs. Shoulder margins provide good seat but a comparatively wider marginal seal. Chamfer, Long chamfer and feather edge margin provide superior sealing of the margins despite poor seat. Among all finish lines, Chamfer margin comparatively shows better marginal seal and occlusal seat. Hence, chamfer margin is recommended for full metal restorations.

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Legendes Figures

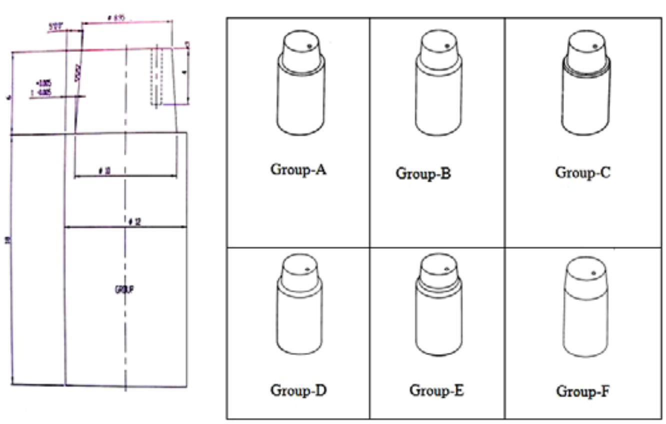

Figure 1a: Diagram of standard die and various finish line preparations used in study.

Group A- Shoulder angled at 90-degree.

Group B -Shoulder angled at 45-degree to the long axis of prepared die. Group C- 90-degree shoulder with 30-degree bevel.

Group D- Chamfer with marginal width of 1mm. Group E- Long chamfer having a larger arc of sphere. Group F - Feather edge margin had no marginal width and 5- degree taper.

Figure 1b: Metal dies of six finish line preparations machined on computerized numerical control (CNC) machine.

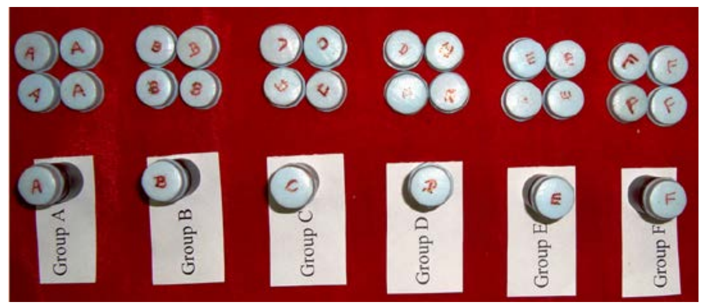

Figure 2: The wax patterns of 1mm thickness made directly on the metal dies using dip wax technique**.**

Figure 3: Dies were indexed to aid proper repositioning during cementation by drawing a vertical line on the acrylic below the vertical groove of metal crown.

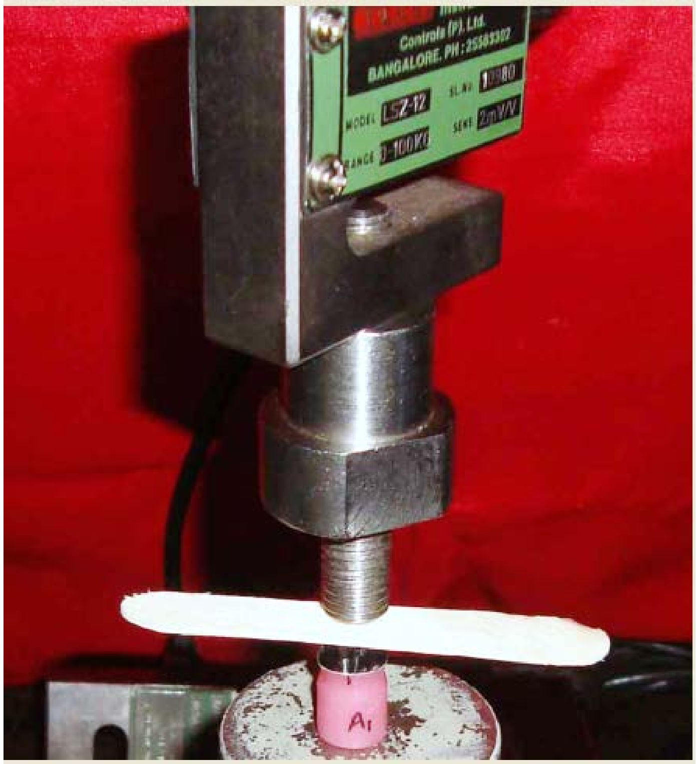

Figure 4: Crowns were cemented under constant load of 5 kg on universal testing machine.

Figure 5: Crown-die assembly embedded in clear acrylic.

Figure 6: Sectioning of embedded crown-die assembly with Carbide disc using water with added detergent as a coolant.

Figure 7: Stereomicroscope used to measure cement spaces.

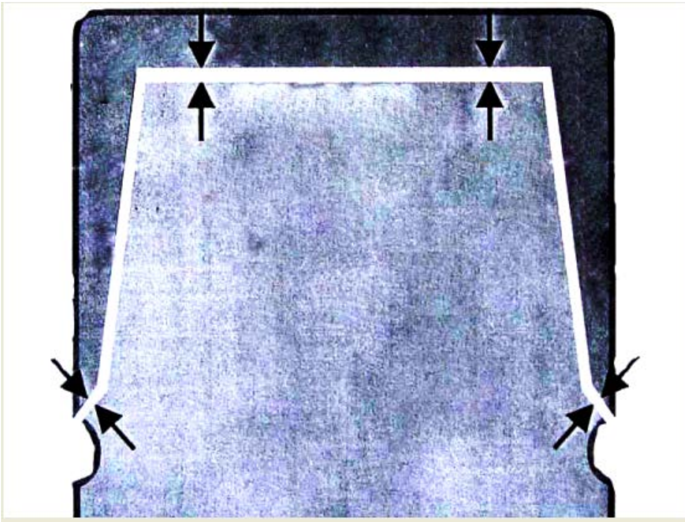

Figure 8: Cement thickness was measured at the position of arrows, two points on the occlusal surface and one at each margin at cervical level.

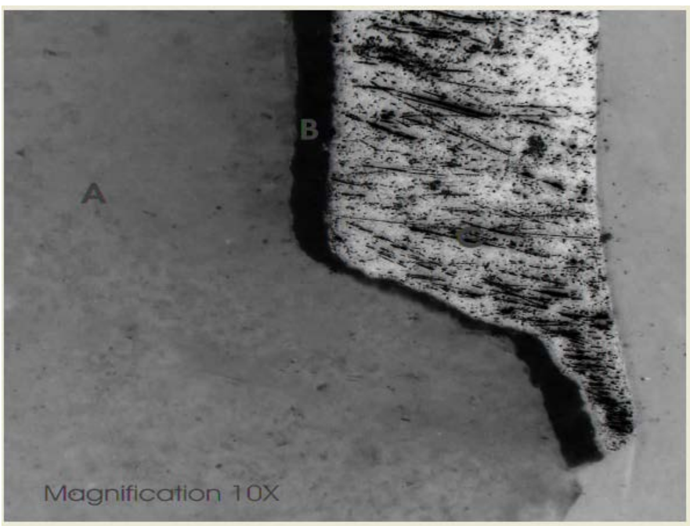

Figure 9a: Photomicrograph of cement spaces at cervical margins (Original magnification 10X). (A=Acrylic die. B=Cement thickness. C=Metal crown. D=Clear acrylic).The cement thickness at the marginal area represents the marginal sealing ability of finish line.

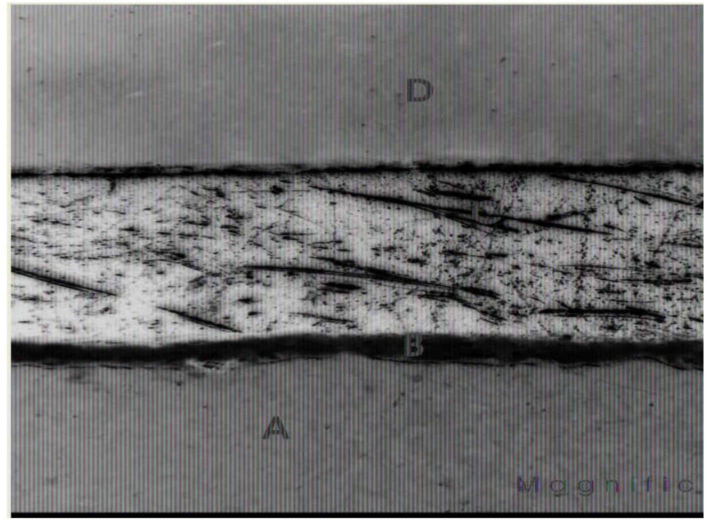

Figure 9b: Photomicrograph of cement spaces at occlusal margins (Original magnification 10X). (A=Acrylic die. B=Cement thickness. C=Metal crown. D=Clear acrylic).The cement thickness at the occlusal surface shows the occlusal seat of the crown.

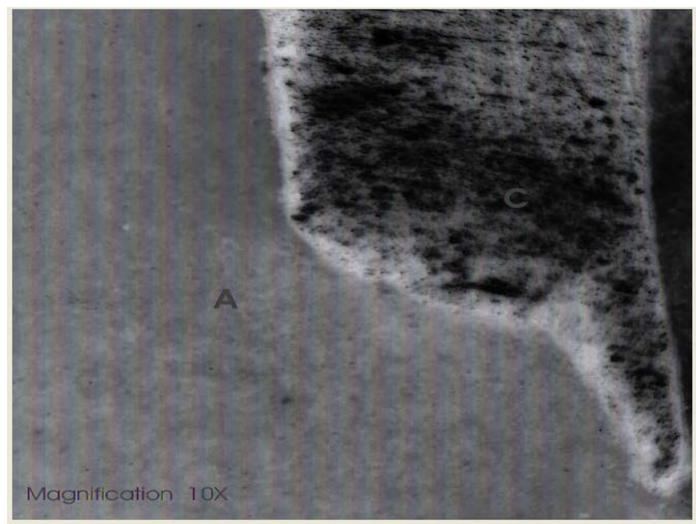

Figure 10: Control group showing no space between metal crown and acrylic (Original magnification 10X). (A=Acrylic die. C=Metal crown. D=Clear acrylic)