COMPARATIVE EVALUATION ON EFFECT OF DIFFERENT SPLINTING MATERIALS IN CAST ACCURACY OF EDENTULOUS MULTIPLE-UNIT DENTAL IMPLANT IMPRESSIONS - AN IN VITRO STUDY

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Abstract:

The accuracy of the implant-supported prosthesis is related to the definitive cast (or “master cast”), who’s precision depends on the impression technique execution and dimensional stability of the splinting materials used. The purpose of this in vitro study was to evaluate the accuracy of the master cast using open tray impression technique and splinted with three splinting materials Bis-GMA temporizing material, light cure tray material, polyether bite registration material. A mandibular reference model with six implants was done. 33 custom trays were fabricated using the light curable resin sheets using medium body polyether impression material. These trays were randomly divided between the three groups, with eleven trays in each group. Impression techniques were divided into three groups namely: Group I: impression copings splinted with Bis-GMA temporizing material, Group II: impression copings splinted with light cure tray material, Group III: impression copings splinted with polyether bite registration material and then final impressions were made. Total of 33 master castswere fabricated. Optical microscope (OPUS 3020T MODEL) CMM, numerical difference in distance between the implants were evaluated. The difference among the three groups, one-way ANOVA, tukey HSD analysis and kruskal wallis test were performed. The results showed significant differences among the materials, as well as their interactions ($P < 0.05$). The master cast obtained by the splinting material Bis-GMA temporizing material, light cure tray material exhibits no difference from the reference model but deviation was found with cast obtained from polyether bite registration material. The Bis-GMA temporizing material and light cure tray material are easy to handle, less time consuming, less technique sensitive, rigid and has its routine utility in clinical practice.

Keywords: Multiple implant impression, splinting material, Bis-GMA, Light cure tray material, polyether bite registration material.

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1. Introduction

Accuracy and Passive fit of multiple implant framework prosthesis, is suggested as one of the critical requirements for long-term implant success. A non-passive framework leads to certain biological and mechanical complications such as screw loosening, screw fracture, occlusal discrepancies, loss of osseointegration, plaque accumulation, soft and hard tissue problems, and bone loss.[1, 2] It may not be probably possible to connect a multi-unit implant prosthesis with a completely passive fit in clinical situation because there are many potential inaccuracies with current materials and techniques, which include dimensional changes in impression materials, expansion of gypsum die product, dimensional changes in wax and acrylic pattern, dimensional changes in investment materials and volumetric shrinkage of metal casting on solidification and the clinicians skill.[3] Among these variables, the precise transfer of the spatial relationships of implants from the mouth to the master cast with an impression is the first and crucial step to ensure passive fit of implant framework. Therefore, clinicians should strive for improving and precise transfer of the impression copings. Investigating multiple impression techniques and materials.[4, 5] Found that consistent distortion resulted from difference in positional change of copings from transfer manipulation. For stabilization of transfer copings from rotation or fastening of analog, widely followed practice is connecting transfer copings with autopolymerizing resin. This maintains the relationship between multiple implants in rigid fashion. The exact advantage was not provided in there study. With the usage rigid impression materials or less flexible elastic materials for stabilizing the copings there is chance for eliminating the factor of polymerizing shrinkage which is evident in resins. Assif et al has advocated usage of impression plaster over auto polymerizing acrylic resin as splinting material due to its rigidity and ease of availability and cost efficacy.[6] Vinyl polysiloxane (VPS) bite registration material splinted impressions showed better accuracy compared to resin splinted and unsplinted group according to Rhyu et al.[7] A lack of parallelism among the implants, and between the implants and the teeth is a common finding in clinic, which is due to anatomical limitations or the esthetic considerations. This may lead to undesirable path of impression withdrawal which is considered as a cause of impression distortion.[6,7,8] In literature, techniques for achieving accurate impression in patients with multiple implants, describes mostly about the techniques for parallel implants impression precision which does not stimulate patients oral conditions and there are only 2 dimensional positional accuracy evaluations. Carr et al studied on impression techniques for angulated implants however very less research was present comparing multiple varying degree of angulated implants.

Experimental:

2. Materials And Methods

Sample Preparation:
Reference Model Fabrication

A mandibular reference model made by 3D printing using Fused Deposition Modelling FDM technology with material polylactic acid in Prusa i3 MK2S Printer, with six implants analogs of standard size, with 6 internal connection for implant analogues of dimensions 3.5 mm × 10mm (ADIN Dental Implant Systems Ltd, India) was fabricated to simulate a clinically relevant situation as A, B, C, D, E, F in predetermine position. A, F in right and left premolar region B, E in canine region C, Din incisor region. A,B,E,F will be placed parallel to each other to standardize the error sequence and C and D is placed at 15 degree angulation. The reference model mimics a mandibular implant-supported overdenture. (Figure 1) Three stoppers, of 1 mm deep and width of 2mm, one in the anterior and two in the posterior region were made in the land area of the mandibular reference model which ensures the proper orientation of the impression trays.[9, 10] The direct scanned measurement got from the mandibular master model was control and used as comparison to values from casts poured from the impressions using different splinting materials on the model.

Preliminary Cast Fabrication

An irreversible hydrocolloid (Zelgan plus, Densply, haryana, India) was used to make mandibular reference model impression. Using a type IV (Ultra real Die stone, Shruti products, Upleta, India) gypsum product cast was fabricated (Figure 2). Two layers (4mm) of baseplate wax (Hindustan Modeling wax Ltd, Hyderabad, India) was heated and adapted to the obtained cast to attain consistent thickness of theimpression material.[11, 12] Only one custom tray was fabricated for each cast .The same procedure was repeated to achieve 33 custom trays.

Fabrication of Custom Tray

33 Custom trays were made using lightcure acrylic resin sheets (VLC Trutray Traid sheets; Dentsply Trubyte Ltd, India) of 2mm in thickness (Figure 3). The impressions are made by open tray method. The light -cured sheet was applied over the spacer wax and carefully adapted to the determined design. The material was adapted to the predicted borders and a scalpel blade (No. 12) was used to remove excess material.[14, 15] The custom trays were fabricated 2mm short of the sulcus to achieve the border seal. Six perforations were made with a round bur (5mm wide) at the site of the implant analogues to provide access for the copings. A handle in center and two detachment wings was placed and contoured. The handle was made with 3 to 4mm thickness and 8mm height and the lateral detachment wings in posterior region were fabricated to provide traction for the uniform tray removal. The completely fabricated tray was polymerized in a visible light curing unit and then verified for 23 irregularities or sharp borders on the reference model and were smoothened using tungsten carbide bur. Perforations were made with a carbide bur to provide retention of impression material on to the tray.[16, 17] (Figure 4)

Impression Procedures

Each trays used for impression making were coated with tray adhesive (Universal VPS adhesive, GC India) before the impressions were made. A thin single and even layer of t ray adhesive was coated on the inner surface of individual tray extending approximately 3 mm beyond borders. 15 minutes of drying period was provided for the adhesive before the impression was made. The tray samples were distributed accordingly into four groups based on the impression technique. (Figure 5) Using n Master software with power of 90% and alpha error 5% sample size was calculated as total of 33 samples were considered for the study, with 11 samples in each group as listed below. Group I : Open tray impression copings splinted with Bis -GMA (Protemp® 3M material), (Figure 6). Group II : Open tray impression copings splinted with light cure resin tray material (Individo lux ®, VOCO) (Figure 7).Group III : Open tray impression copings splinted with bite registration polyether (Rami tec®, 3M) (Figure 8). A total of 33 polyether impressions were made with copings splinted with 3 different splinting materials and polyether impression materials from the master model. The 3 splinting materials tested were Bis-GMA Pro-temp® 3M 4 , light cure resin tray material (Individo lux ®, VOCO) , bite registration polyether (Rami tec®,3M). The impressions were made using open tray. Each impression was made with uniform quantities of impression material. The impression material was allowed to set according to manufacturers.

The torque wrench calibrated at 10N-cm was used to secure the copings (Figure 9). Impressions were made with direct implant impression technique. Throughout the polymerization time the impression was seated and maintained in position on 3 orientation marks which is guide stop. The single operator made all the impressions. Group I : Open tray impression copings splinted with Bis-GMA Protemp ® 3M material waxed dental floss (Oral B Company, Chennai , India), was wrapped around the square copings and splinted together then linked the transfer copings with the application of Bis -GMA Protemp ® 3M material , to the scaffolding of dental floss before impression (Figure 10). Resin was dispensed on and around the transfer copings by incremental application using a brush. The square surfaces of coping was fully covered with about 2mm thickness ensuring the adequacy of material. Once the material is set impression was made (Figure 11). For each impression newly fabricated resins bars are used. The impression tray was seated, and the impressions were made with a direct open tray technique using polyether material and the material was allowed to set. Lab analogues were secured to the impression transfer copings before cast was poured. Group II, open tray impression copings splinted with light cure resin tray sheet (Individo lux ®, VOCO). With help of regular dental floss (Oral B Company, Chennai, India) the transfer copings were connected following which, the copings were splinted together tray sheets which was cut into 4mm wide 7cm length (Figure 12). This was cured according to manufacturer recommendation. The impression material was loaded in the special tray and syringed around the transfer copings. After the material is set the tray was removed. Impressions were examined for any inaccuracies such as separation from tray, deficiency of material, voids and repeated if required.[18, 19] The manual torque was used to remove the copings from the definitive cast, ensuring that the transfer copings remained in position after the impression removal. Each transfer coping, new analogs were connected. Group III, Direct impression technique with open tray impression copings splinted with bite registration polyether (Rami tec®, 3M) (Figure 13).The bite registration paste was dispensed onto flows matrix on the impression copings and was allowed to set according to manufacturer's recommendation. The same impression procedure is followed. The impression procedure followed and impression material used for Group I and Group II and III were similar expect the materials used for splinting varies.

Making of Stone Casts

Lab Analogues were secured onto the transfer copings in impression (Figure 14). Each of the 33 impressions were poured in an ADA-certified type IV dental stone (Ultra Rock die stone, Shruti products, Upleta, India) according to the manufacturer 's recommendation. A 100g package of Prima Rock stone was mixed with 28 ml of water with a vacuum mixer and then carefully poured into the impressions to avoid air bubbles and it was allowed to set for 60 minutes. Only one cast was formed from one impression.[9, 20] For a minimum of 24 hours before the measurements, all cast were stored in room temperature made (Figure 15).

Measurements

For recording coordinate points of the lab analogs of implants on the master model and samples in 3 dimension Optical microscope(OPUS 3020T MODEL), coordinate measuring machine was used.(Figure 16) The same operator using probe head and signal probe performed al l measurements.(Figure 17) The input information from probe of 0.5 mm was read and sent to software and measurement was converted from 3D data to numerical data as distance between analogues using the Euclidean distance formula.(Figure 18) Distance between the analogues was calculated.[21, 22] For each cast and master model measurements were taken 5 times. The same-blinded operator recorded all measurements. In a spreadsheet (Microsoft Excel) the values were recorded and at a confidence level of 95%, Oneway analysis variance was used to evaluate the data, to determine significant differences between the groups and post -hoc tukey HSD test was used for statistics.

The intent of the research work was to analyze and compare precision of multiple implant splinted using three materials visible light cure tray material, Bis-GMA and medium body polyether impression material. An aggregate of 33 specimens were considered for the study, which had 11 test specimens in each group. The distances measurement in x, y, z plane between the implants were attained and the average was determined for three groups. Horizontal , vertical and the third axis distances measured were AB, AC, AD, AE, AF (between the implants). With the use of Optical microscope (OPUS 3020T MODEL) numerical difference in distance between the implants were analyzed. To find the difference among the three groups, one –way ANOVA, tukey HSD analysis and kruskal wall is test were performed. One-way ANOVA showcased that there were significant differences among the materials, as well as their interactions ($P < 0.05$). Tukey HSD test was performed for multiple comparisons. With 95% confidence interval and the significance level of 5% Data were then analyzed.

3. Results:

The mean and standard deviation obtained for the horizontal distance AB is tabulated in table 1. The mean of the horizontal distance AB for each group was 40.46782, 40.46436, 39.63482, and 40.18900. The derived mean and standard deviation for the horizontal distance AC is presented in table 2. The mean of the horizontal distance AC for each group was 33.55045, 34.26000, and 34.25127. Table 3 represents the mean and standard deviation of the horizontal distance AD. The mean of the horizontal distance AD for each group was 23.57045, 23.69973, and 25.58055. The mean and standard deviation for the horizontal distance AE is listed in table 4. The mean of the horizontal distance AE for each group was 13.68091, 13.34300, and 14.54364. The attained mean and standard deviation for the horizontal distance AF is tabulated in table 5. The mean of the horizontal distance AF for each group was 3.87018, 4.47918, and 6.42491. The combined mean and standard deviation of the horizontal distances between and within groups were tabulated in table 6. It shows the one- way ANOVA analysis of the mean values and the significant difference between and within the groups. The F value was calculated from the mean value, from which the P value was calculated. The P<0.05, was value considered to be significant statistically.Here AB, AD, AE, AF were statistically significant .Table 7 to 11 shows the significance level of the three groups by multiple comparisons between the groups for horizontal distance AB - AF. Multiple group comparison within the groups was done using tukey's HSD post Hoc test. The significance value P <0.05, was regarded as significant statistically. From the values obtained, it was appreciated that there was significant variation detected between group III and I and group III and II Groups in horizontal distance AD, AE, AF. Graphical representation of comparison of inter implant distance X axis three groups along with control model in graph 1.The mean and standard deviation obtained for the Vertical distance AB is tabulated in table 12. The mean value obtained for the Vertical distance AB of each group was 2.44336, 2.60764, and 1.14327. The mean and standard deviation of the Vertical distance AC is tabulated in table 13. The mean of the Vertical distance AC for each group was 12.70882, 12.24864, and 9.07985. Table 14 denotes the mean and standard deviation of the vertical distance AD. The mean of the Vertical distance AD for each group was 15.12555, 14.60136, and 12.52191. The corresponding mean and standard deviation of the Vertical distance AE is tabulated in table 15. The mean of the Vertical distance AE for each group was 14.19027, 14.14727, and 13.31582. The derived mean and standard deviation of the Vertical distance AF is tabularized in table 16. The mean of the Vertical distance AF for each group was 8.25173, 9.25873, and 7.44500. The combined mean and standard deviation of the Vertical distances among and within the groups is tabulated in table 17. It shows the one-way ANOVA analysis of the mean values and the significant difference between and within the groups. The F value was calculated from the mean value, from which the P value was calculated. The P <0.05, was value considered to be significant statistically. Table 18 to 22 shows the significance level of the three groups by multiple comparisons between the groups for Vertical distance AB – AE. Multiple group comparison within the groups was done using tukey's HSD post Hoc test. The significance value of P<0.05, was regarded as significant statistically. From the values obtained, it was appreciated that, significant variation was detected between the group III and I and group III and II in Vertical distance expect in AE. Graphical representation of comparison of inter implant distance Y axis three groups along with control model in graph 2. The mean and standard deviation obtained for the Z axis AB is tabulated in table 23. The mean value obtained for the x axis AB of each group was 1.62491, 1.81391, and 2.44891. The mean and standard deviation of the Z axis AC is tabulated in table 13. The mean of the Z axis AC for each group was 3.20873, 3.02182, and 3.67164. Table 25 denotes the mean and standard deviation of the Z axis AD. The mean of the z axis AD for each group was 3.34173, 2.75194, and 4.13691. The corresponding mean and standard deviation of the Z axis AE is tabulated in table 26. The mean of the Z axis AE for each group was- .38955, - .37518 -1.60918. The derived mean and standard deviation of the Z axis AF is tabularized in table 27. The mean of the Z axis AF for each group was- .76618, - .91600 2.33782. The combined mean and standard deviation of the Z axis among and within the groups is tabulated in table 29. It shows the one- way ANOVA analysis of the mean values and the significant difference between and within the groups. The F value was calculated from the mean value, from which the P value was calculated. The P <0.05, was value considered to be significant statistically. Table 30 to 33 shows the significance level of the three groups by multiple comparisons between the groups for Z axis AB – AE. Multiple group comparison within the groups was done using Tukey's HSD post Hoc test. Kruskal Wallis test was performed for AE, AF as the mean value obtained was negative. The significance value of P <0.05, was regarded as significant statistically. From the values obtained, it was appreciated that, significant variation was detected between the group III and I and group III and II in vertical distance expect in AB, AC. Graphical representation of comparison of inter implant distance Z axis three groups alongwith control model in graph 3.The mean and standard deviation obtained for the implant Angle A1 is tabulated in table 34. The mean value obtained for A1 of each group was 89.87845, 88.18491, and 86.38882. The mean and standard deviation of the implant angle A2 is tabulated in table 35. The mean of A2 for each group was 88.12855, 88.48391, and 85.71273. Table 36 denotes the mean and standard deviation of the implant angle A3.The mean of the A3 for each group was 92.30218, 92.02109 and 93.21755. The corresponding mean and standard deviation of the implant angle A4 is tabulated in table 37. The mean of A4 for each group was 91.99255, 92.09782, and

92.46636. The derived mean and standard deviation of the implant angle A5 is tabularized in table 38. The mean of A5 for each group was 89.29973, 88.57545, and 85.97100. The derived mean and standard deviation of the implant angle A6 is tabularized in table 39. The mean of A6 for each group was 89.43773, 88.71500, and 88.28655. The combined mean and standard deviation of the angle among and within the groups is tabulated in table 40. It shows the one way ANOVA analysis of the mean values and the significant difference between and within the groups. The F value was calculated from the mean value, from which the P value was calculated. The P <0.05, was value considered to be significant statistically. Table 41 to 46 shows the significance level of the three groups by multiple comparisons between the groups for Angle A1 -A6. Multiple group comparison with in the groups was done using tukey's HSD post Hoc test. The significance value of P <0.05, was regarded as significant statistically. From the values obtained, it was appreciated that,significant variation was detected between the group III and I and group C and II in Zaxis expect in A3, A4, and A6. Graphical representation of comparison of Implant Angulations of A1-A6 in three groups along with control model in graph 4**.** The comparison of mean distances of the duplicative casts of the three groups obtained from three different splinting materials (visible light cure tray material, Bis-GMA temporizing material, medium body polyether ether impression material), polyether impression material showed significant difference from master model in X except in AC, Y except in AE, Z axis except in AC and Implant Angulation except in A3, A4, A6. No statistical difference was found with Visible light cure tray material and Bis-GMA splinted groups. From the data obtained, statistically significant variation was detected among the group C.

4. Discussion:

As of late, the implant therapy is more predictable treatment option for edentulous conditions. Absence of periodontal ligament is the fact that the implants cannot tolerate even minor superstructure misfit. Achieving an accurate and passive fit of implant prosthesis and transferring implant position through precise impression is key for success and longevity of the prosthesis.[6, 8] Materials used for implant impression, especially multiple implant impression has to record details precisely and must retain the original dimensions and positions of implant until the cast is retrieved. The inappropriate positional details can produce an unfavourable consequences in final fit of the prosthesis. There can be movement or change in position or angulation in multiple implant situations during impression making. Therefore to overcome this problem splinting of multiple implants during impression making is been followed widely. The use of appropriate impression material and technique aids in better harmonization of dental implant components. There are many studies, evaluating different impression materials, splinting materials and techniques. There is no definitive evidence observed till date that exact applicability of ideal impression material for multiple implant impressions because of variability and inconclusive results of the study. Endosseous dental implants are placed inside the residual bone, from which abutment projects for the attachment of superstructure. To replicate the implant position in the cast, a component called as impression or transfer coping is secured onto the implant impression. There have been two implant impression techniques that is followed traditionally. The open tray or direct technique and closed tray or indirect technique. In the open tray method, either custom or stock impression tray is utilized. Impression coping is attached to the implant with the help of a screw connection and impression is made.[23, 24] In stock tray technique, an opening is created on the tray creating a space for the transfer coping. The coping is unscrewed to retrieve the set impression. Lab analog is secured on to the transfer coping in the impression to replicate the position of implant on the model. In closed tray method, the copings prevail in the oral cavity while set impression is removed. Abutments are approximated on the impression with the indentation marks and the lab analogue is attached before making the cast. The poly vinyl siloxane and polyether are most commonly used for implant impressions. Unlike natural teeth, maintenance of accurate position of coping with analog inside the impression is of absolute importance. The minor movements of components can have an impact on passive fit of implant superstructure. Both the impression materials have limitations of their own which led to the development of new vinyl polyether silicone impression material. Studies by Vigolo et al and Aguilar et al have evaluated different impression techniques with addition silicone and polyether for implants.[25, 26] But only few studies done by Barett et al, Dario et al and Hinds et al have evaluated the impression techniques for multiple implants with vinyl poly siloxane material.[8, 9] Vojdani et al and Thongthammchat et al in their study supported the use of PVS impression material for partially edentulous multi -unit angulated implant impressions.[18, 23] Ongul et al and Seyedan et al observed both addition silicone and polyether, which produced comparable inaccuracies in direct impression method.[19,20] Lee et al, Sorrentino et al and Thongthammachat et al evaluated on the factors influencing implant impression techniques followed in clinical practice.[16,17] It was ascertained that no universal impression technique or material could be used for all clinical situations. Lee, Kim et al proved that open tray direct technique produced superior precision in clinical situation for more than three implants.[25, 29] The chance of error is less compared to indirect method since the transfer coping is retained in the impression. There are more confounding factors when multiple implants are placed in a completely edentulous situations. In multiple implants, splinting of implants is done to replica their original positions in impression making. The efficacy of splinting material plays a significant role in duplication of implant position. In comparison between splinting and non-splinting impression techniques, splinting impression technique demonstrated superior results.[1, 4, 6] Various authors have suggested different materials for splinting of implants. Dental floss or orthodontic wire was used as a scaffold for intraoral splinting with self -cure resin material by Branemark et al.[5] Few authors inferred mechanical means like air borne abrasion of impression coping or use of impression adhesive to shield the position of implant.[5, 28] Auto polymerizing resin material,applied for implant splinting can be custom made or it is also available as preformed resin bars of definitive dimension. In this present study, specific guidelines were adhered for custom fabrication of resin splinting of implants. The use of resin splint resisted the rotation of coping during analog attachment and served to obtain a precise impression.[29, 30]

In this present study**,** Bis-GMA, medium body polyether, visible light cure tray material were used. There were many studies done on the multiple implant splinting impression techniques, not many analyses have been done with Bis-GMA, medium body polyether, visible light cure tray material, open tray technique for multiple implant impressions.[17,18] The literature is not specific about the technique or splinting material for multiple implants impression. Hence this study was done to obtain an ideal splinting material for making multiple implant impressions**.**

Favourable properties like sharpness in reproducibility, stiffness low shrinkage and dimensional stability are necessary to function as a splinting material.[6,7] Additional properties required for an ideal splinting material is stiffness or modulus of elasticity. Bis-GMA, visible light cure tray material, polyether are stiffer and show less shrinkage.[21,22] Only few research is done on the applicability and no comparativestudy of these material in implant impressions were made. Thus, in this in- vitro study these materials were selected for evaluation of its accuracy. Light polymerizing resin is preferred over auto polymerizing resin as it possesses better mechanical properties like increased stiffness, low polymerizing shrinkage and so there is no need for sectioning and rejoining to compensate for polymerizationshrinkage, ease of handling as it is availablein form of sheets, no need of supporting dental floss and better patient comfort. Even though splinting materials rigidly holds copings together, the time consumption for splinting those transfer copings and impression making is higher. Using Bis-GMA reduces the time for impression making as it provides a comfortable application mode, faster setting time, minimal shrinkage as it is temporizing material ease of use intra orally and readily available at most clinics .The data regarding the accuracy of this material for splinting purpose is very minimal in literature.

Among the available rubber based impression materials there are certain materials which were studied for their accuracy as splinting materials such as polyether and poly vinyl siloxane. Polyether impression material is stiffer compared to poly vinyl siloxane.

Stiffness of impression material is advantageous property to obtain passive fit of the prosthesis. There are studies stating that polyether impression material is superior to poly vinyl siloxane.[7] It is difficult to quantify the three -dimensional implant position. Measurement devices are now available to analyze the positional deviations of objects. Equipments like co-ordinate measuring machine, three-dimensional photogrammetry and University of Michigan systems are some of the usable devices. Among the current available measurement methods, photogrammetry records 3 dimensional details by taking intraoral pictures using a scanner. Its effectiveness is questionable when multiple implants are placed. On the other side, the Coordinate measurement machine can be very practically used when positional deviations are studied outsidethe oral cavity on the casts. Vojdani et al demonstrated that a coordinate measurement machine quantifies implant linear and rotational positional variation in all three axes (X, Y and Z).[4] Henceforth coordinate measurement machine (CMM) was used as a device to locate deviations in this study. This machine consists of a flat platform for the investigation model to be placed and mechanical probe, which was dispensed to move and locate deviations in all axes. As the machine was computer controlled, data was directly obtained from the computer software with less chance of human errors. The centroid points over implant heads were automatically detected using computer control system as lines were drawn in X, Y and Z axis to generate values. A comparison between the groups was done in X, Y and Z axis with implant A as a standard reference implant, from which other implant distances were calculated.

The comparison of mean distances of the duplicative casts of the three groups obtained from three different splinting materials (visible light polymerizing tray sheet ,Bis-GMA temporizing material , medium body polyether ether impression material) , polyether group showed significant difference from master model in (X axis , Y axis, Z axis) and implant angulation except in A3, A4, A6.

On comparing the accuracy of master casts made from Bis-GMA and Visible light cure tray material , the readings obtained were close to the reference model and the readings which is obtained from the cast made from polyether impression showed greater difference with the reference model and also with other two groups. The Bis-GMA and Visible light cure tray material showed the same amount of variation from the reference model and these splinting materials were statistically similar in all the three dimensional X, Y and Z axis.

The inference of the present study is drawn from an in –vitro research design. Impressions were made in extra oral environment without the presence of natural tissues and oral fluids like saliva, blood which may influence the exactness of impressions. The study was done using one specific implant system, its results applicability with other systems has to be compared. Determination of impression material accuracy beyond 24 hours and extended time span can be done to continue with further research. Further studies correlating the conclusion with clinical research trials are essential to derive the accurateness of implant impression technique and material.[31] In clinical situations, multiple implant impression making is one of the vital procedures in the entire treatment. It mandates proficient skill and knowledge in selection of right splinting material.

The Bis-GMA temporizing material and light cure tray material are easy to handle, less time consuming, less technique sensitive, rigid and commonly used materials in clinics.

The accuracy of implant prosthesis is directly related to precision of implant impression. To obtain positional accuracy and eliminate minor movements of transfer coping, proper splinting as to be carried out with material which possess good dimensional stability and stiffness irrespective of parallel or non-parallel implants.[32] The determination of the accuracy among various splinting materials when multiple implants more than four are placed in mandibular arch was the main intent of this investigation. In this in vitro research, a 3D printed reference mandibular model were fabricated with 6 internal connection implants (A, B, C, D, E, and F) of dimensions 3.5 mm × 10 mm to simulate a clinically relevant situation. CAD CAM is the future and has more reliable accuracy than manual method of fabricating master model. The implant analogues were placed in incisors, canine and premolar region where analogs in incisor region were placed 15 degree angulated to stimulate oral condition rather than all implants placing parallel. The study had 3 experimental groups with 11 samples in each group. From the master model, an aggregate of 33 specimens wereconsidered for the study and impressions were made with open tray direct impressiontechnique. The 3 splinting materials tested were Bis-GMA, medium body polyether, visible light cure tray material. Impressionmaterial used was medium body polyether. The impression procedure followed for Group II and Group III were similar to the ones followed for Group I except for the splinting material. Visible light cure material were used in-group I, Bis-GMA used for Group II and bite registration polyether group III. Each of the 33 impressions was poured using highstrength die stone. Coordinate measuring machine was utilized to quantify thehorizontal and vertical inter – implant distances, third axis and implant angulation. The distances measured between implants were accomplished and then the mean ± SD was documented for allthe three groups.

Statistical analysis was done to determine the intra and inter group significance. No significant variation was observed in Bis-GMA, visible light cure tray material splinted group. For a completelyedentulous situation where multiple implants are placed, study on comparison of different splinting material with Bis-GMA, visible light cure tray material and medium body polyether revealed impressions made using Bis-GMA and VLC material exhibit better accuracy when compared with polyether bite registration material.

5. Conclusion

In correspondence to limitations of this research, the below mentioned conclusions were out lined:

1. Comparing the casts obtained from medium body polyether splinting material with reference model there was significant difference in inter implant distance and angulations.
2. Insignificant variation in dimensional accurateness was observed in Bis-GMA temporizing material and visible light cure tray material on comparison with the reference master model.
3. Statistically significant results were obtained when copings are splinted with medium body polyether impression material to Bis-GMA and visible light cure tray material.
4. No statistical significant difference seen between Bis-GMA and light cure tray material obtained inter implant distance and angulation.
5. The inference extracted from this research was that Bis-GMA temporizing material and visible light cure tray material are dimensionally accurate and are better splinting material for multiple parallel and angulated implants.

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Figures

Figure 1. 3D Printed master model with implant analogues (Control model)

Figure 2. Duplicated master model for custom tray fabrication

Figure 3. Custom made impression tray

Figure 4. Custom made implant impression trays

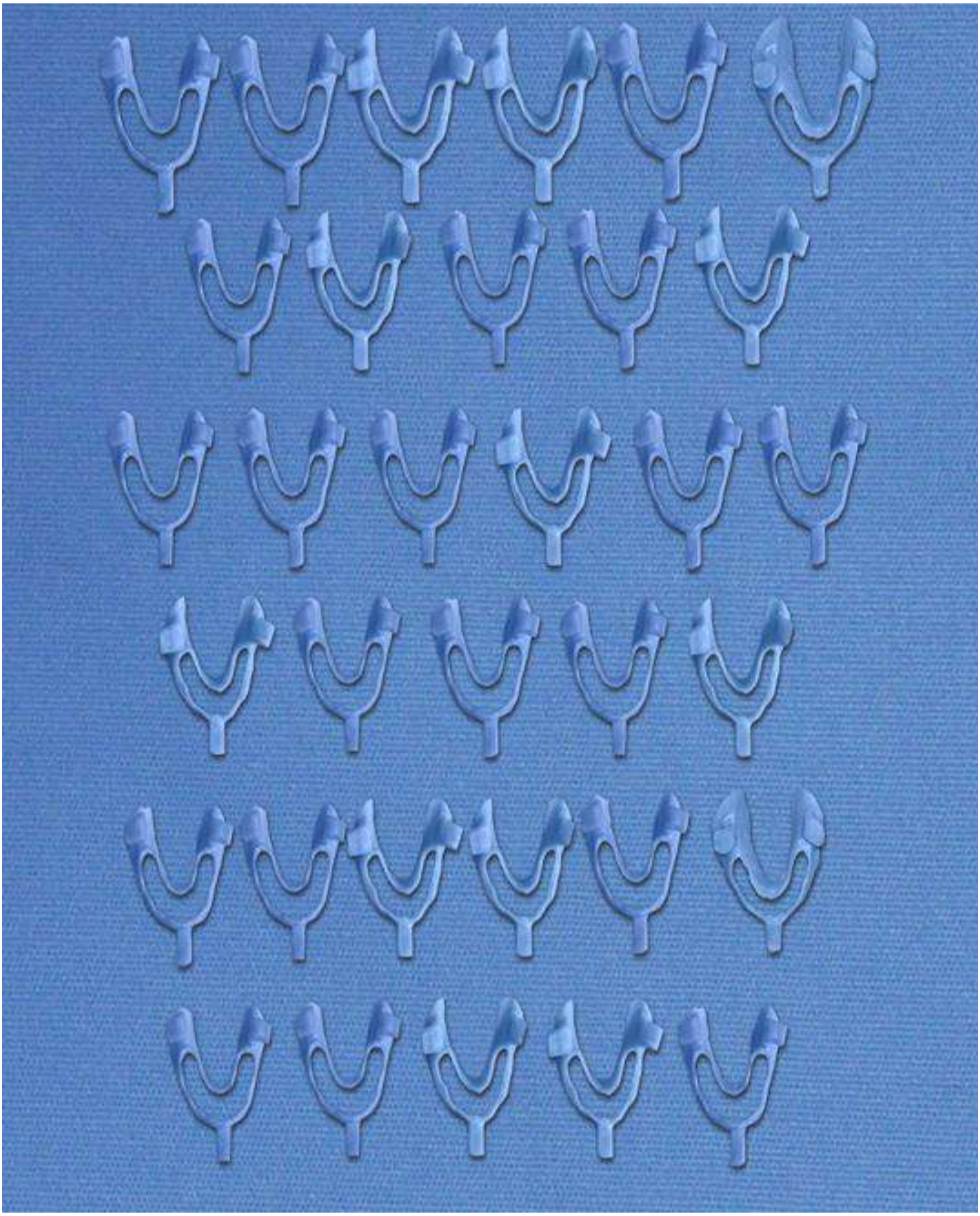


Figure 5. Medium body polyether impression material

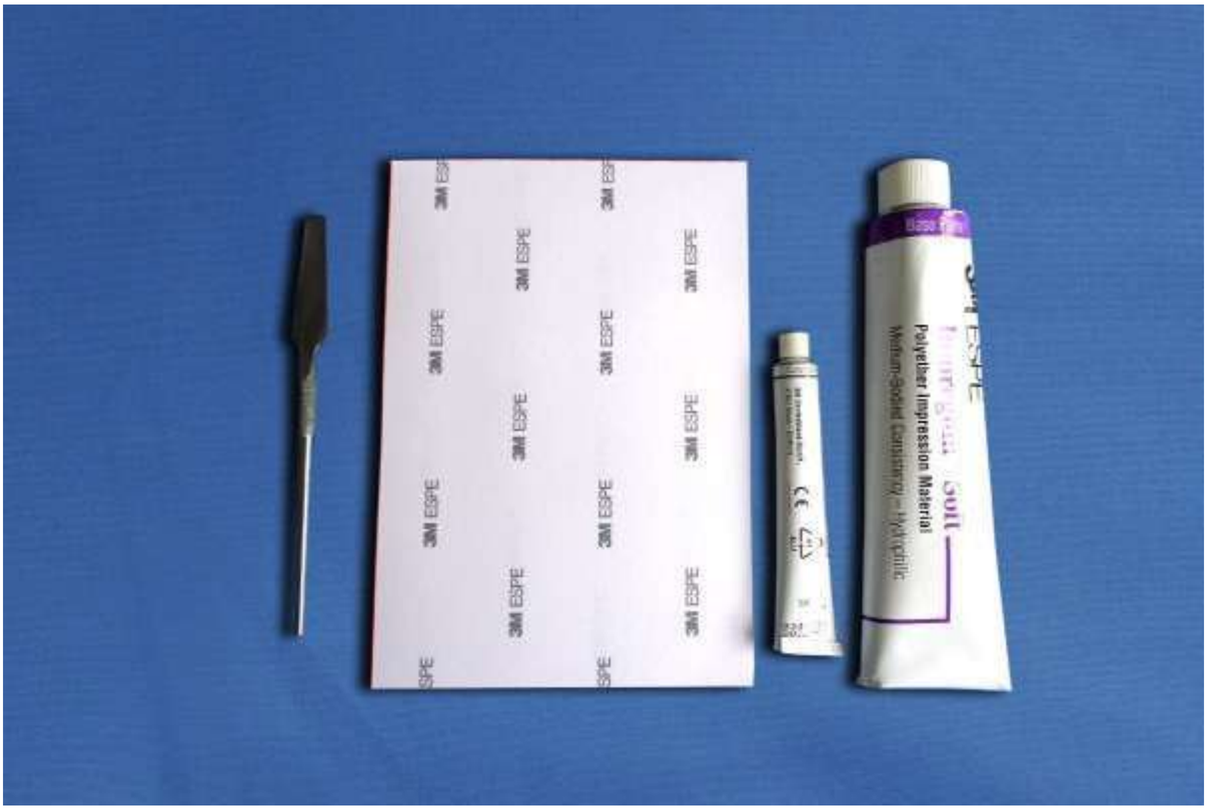


Figure 6. Bis-GMA temporizing material

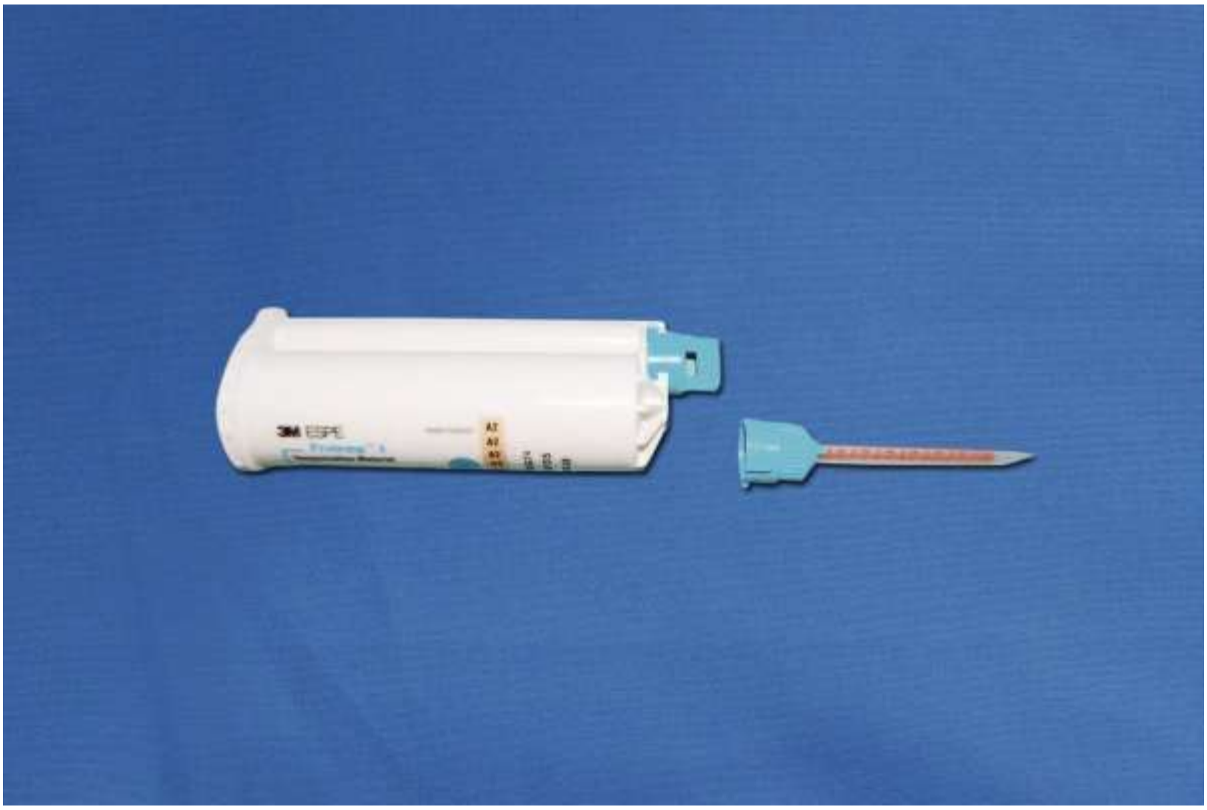


Figure 7. Light cure tray material

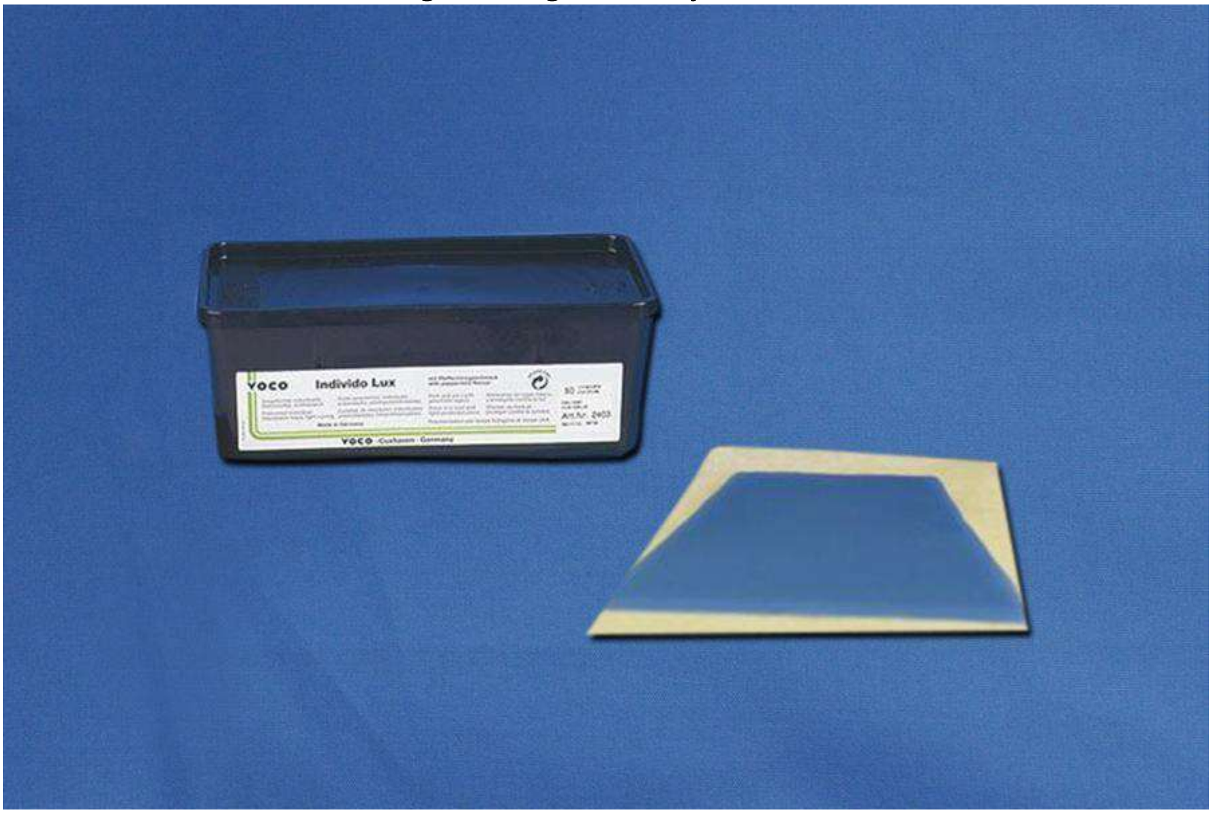


Figure 8: Polyether bite registration material

Figure 9. Master model with transfer copings fixed to the implant analogues

Figure 10. Regular dental floss connecting copings together

Figure 11:Transfer copings splinted using Bis-GMA temporizing material

Figure 12. Transfer Copings splinted using light cure tray material

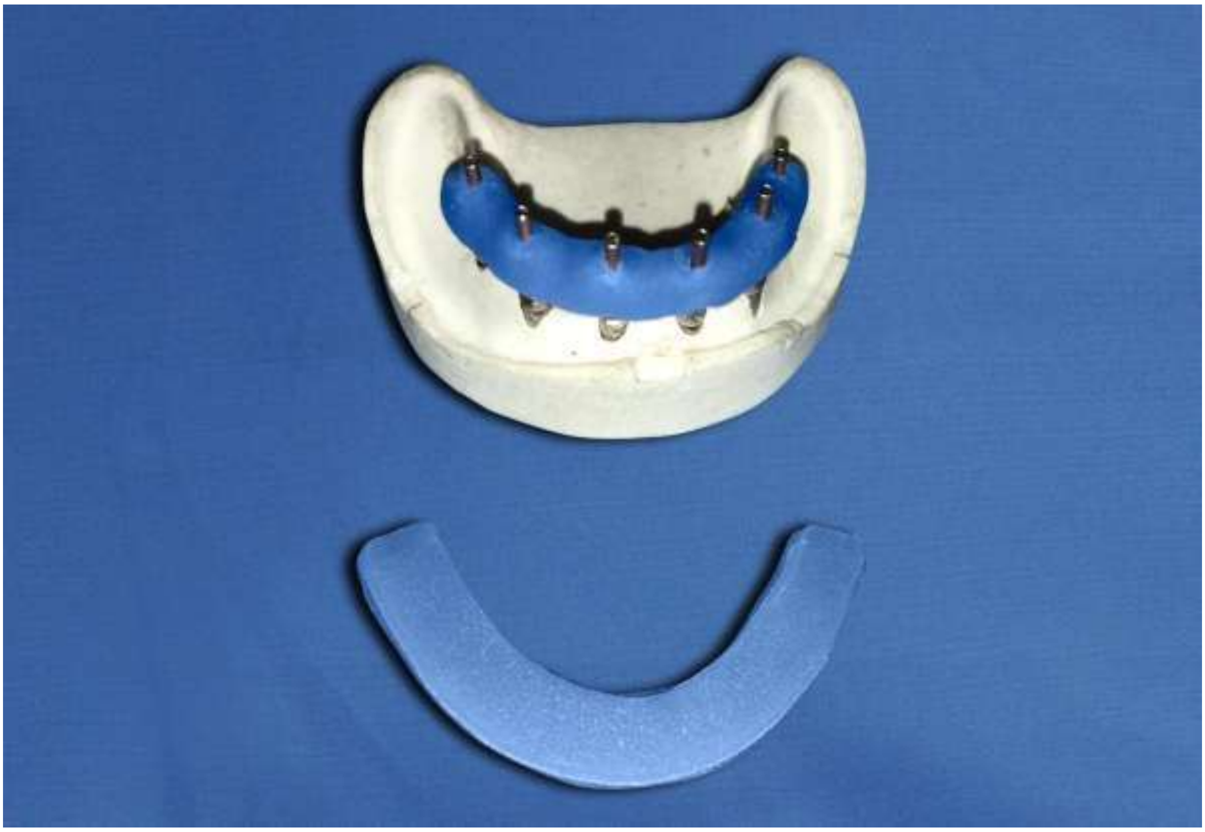


Figure 13. Transfer copings splinted using polyether bite registration material

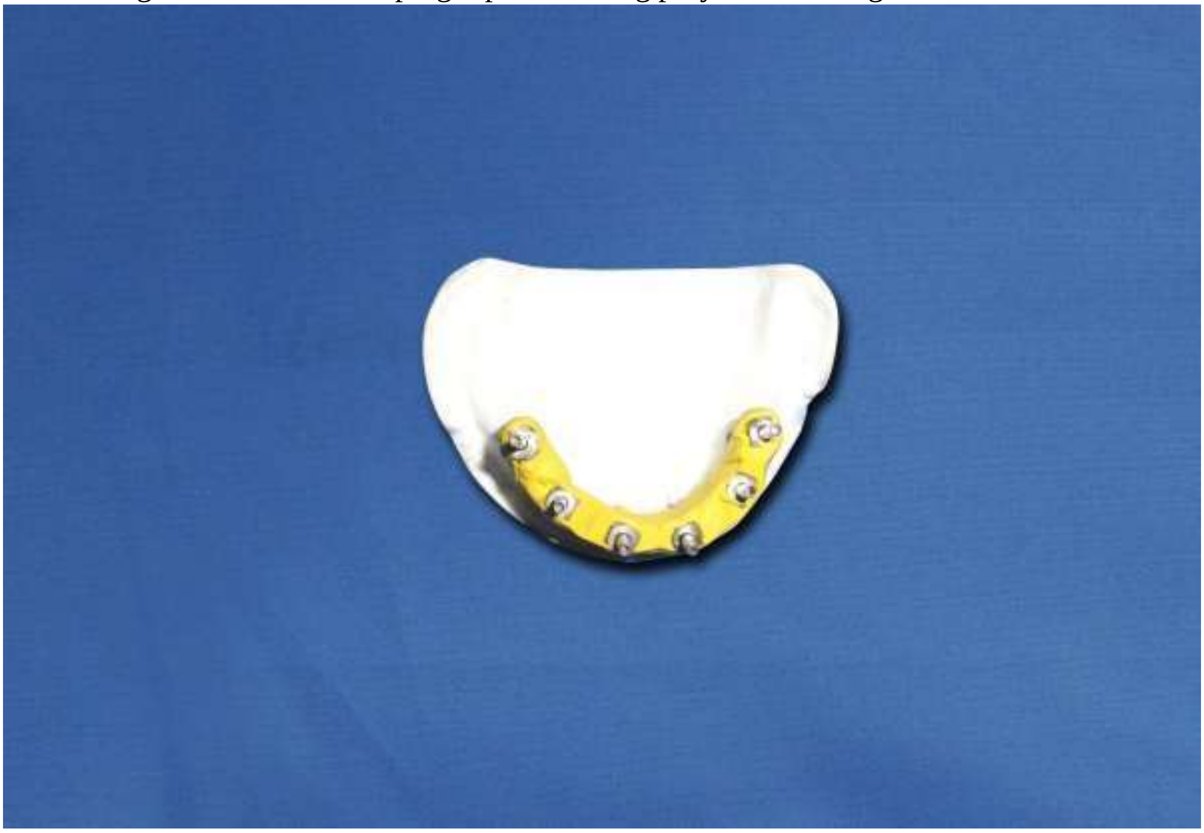


Figure 14. Impression of master model with analogues secured to transfer copings

Figure 15. Casts obtained from master model

Figure 16. Measurement of the dimensions

Figure 17. Co –ordinate measuring machine measuring the sample

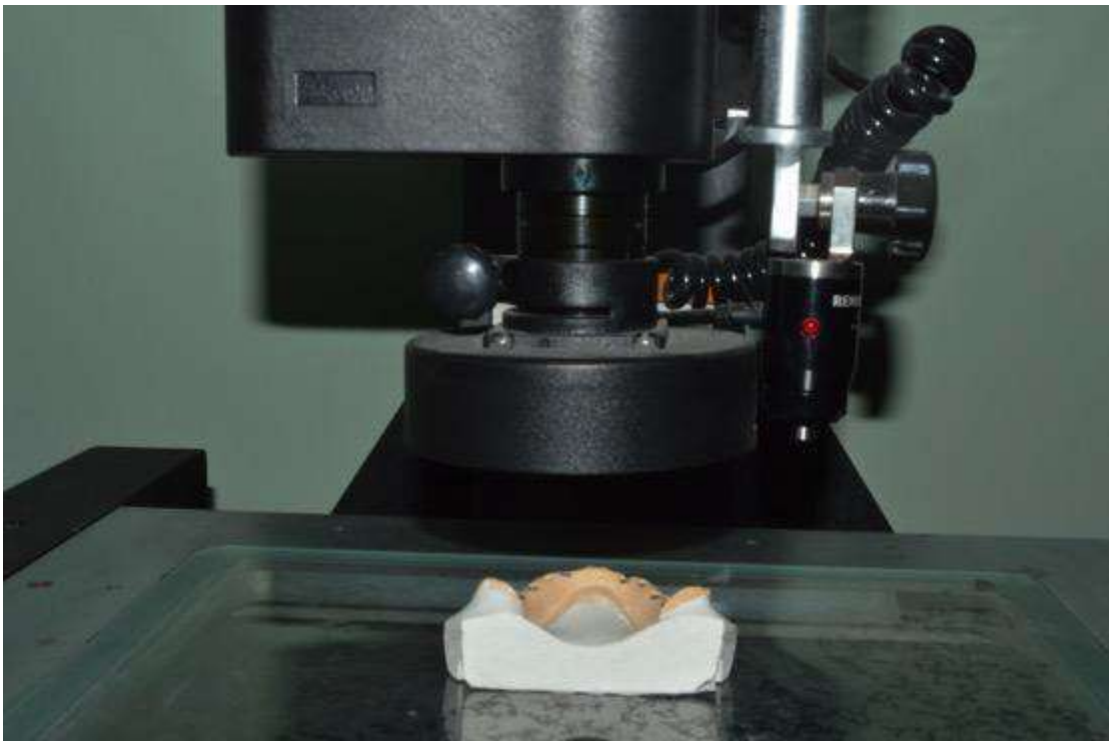
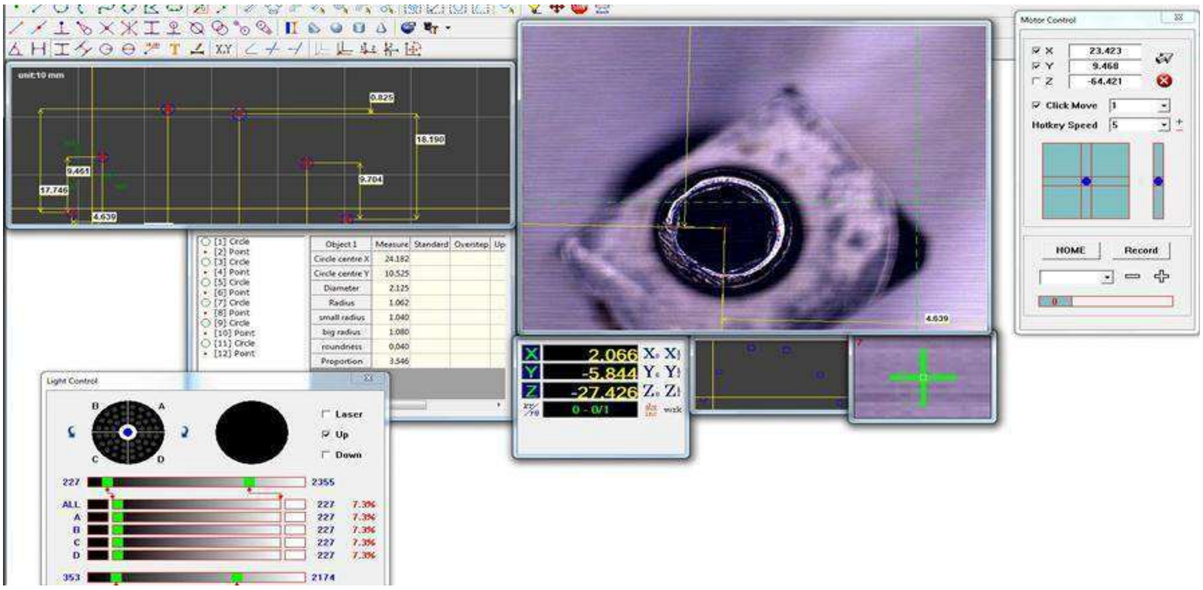


Figure 18. Measurement in X,Y,Z axis for reference implant A



Tables

Table 1. Horizontal distance x value – AB

		N	Mean	Std. Deviation
	Group I	11	40.46782	.726283

AB – X	Group II	11	40.46436	.268933
	Group III	11	39.63482	1.358625
	Total	33	40.18900	.960538

Table 2. Horizontal distance X value - AC

	Group I	11	33.55045	1.176588
	Group II	11	34.26000	.442331
AC– X				
	Group III	11	34.25127	2.037319
	Total	33	34.02058	1.380185

Table 3. Horizontal distance X value - AD

	Group I	11	23.57045	1.173039
	Group II	11	23.69973	.657765
AD– X				
	Group III	11	25.58055	1.266259
	Total	33	24.28358	1.391581

Table 4. Horizontal distance X value - AE

	Group I	11	13.68091	1.261761
	Group II	11	13.34300	.639485
AE – X				
	Group III	11	14.54364	.976090
	Total	33	13.85585	1.089305

Table 5. Horizontal distance X value - AF

	Group I	11	3.87018	1.140078
	Group II	11	4.47918	.702078
AF – X				
	Group III	11	6.42491	1.170710

	Total	33	4.92476	1.487499

Table 6. The combined mean and standard deviation of the horizontal distances between and within the groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups AB – X	5.068	2	2.534	3.108	.059
Within Groups	24.457	30	.815		
Total	29.524	32			
Between Groups AC - X	3.647	2	1.824	.955	.396
Within Groups	57.310	30	1.910		
Total	60.957	32			
Between Groups AD - X	27.847	2	13.924	12.242	.000
Within Groups	34.121	30	1.137		
Total	61.968	32			
Between Groups AE - X	8.433	2	4.217	4.283	.023
Within Groups	29.537	30	.985		
Total	37.971	32			
Between Groups AF - X	39.172	2	19.586	18.575	.000
Within Groups	31.633	30	1.054		
Total	70.805	32			

Table 7. The significance level of the three groups by multiple comparisons between the groups for horizontal distance: AB

Dependent Variable	(I) Sample Description	(J) Sample Description	Mean Difference (I-J)	Sig.
AB – X	Group I	Group II Group III	.003455 .833000	1.000 .094
	Group II	Group I Group III	-.003455 .829545	1.000 .096
	Group III	Group 1Group II	-.833000 -.829545	.094 .096

Table 8. The significance level of the three groups by multiple comparisons between the groups for horizontal distance: AC

AC – X	Group I	Group II Group III	-.709545 -.700818	.460 .469
	Group II	Group I Group III	.709545 .008727	.460 1.000
	Group III	Group I Group II	.700818 -.008727	.469 1.000

Table 9. The significance level of the three groups by multiple comparisons between the groups for horizontal distance: AD

AD – X	Group I	Group II	-.129273	.956
		Group III	-2.010091*	.000
	Group II	Group I	.129273	.956
		Group III	-1.880818*	.001
		Group I	2.010091 *	.000

	Group III	Group II	1.880818 *	.001

Table 10. The significance level of the three groups by multiple comparisons between the groups for horizontal distance: AE

AE – X	Group I	Group II	.337909	.707
		Group III	-.862727	.120
	Group II	Group I	-.337909	.707
		Group III	-1.200636*	.021
	Group III	Group I	.862727	.120
		Group II	1.200636 *	.021

Table 11. The significance level of the three groups by multiple comparisons between the groups for horizontal distance: AF

AF– X	Group I	Group II	-.609000	.358
		Group III	-2.554727*	.000
	Group II	Group I	.609000	.358
		Group III	-1.945727*	.000
	Group III	Group I	2.554727 *	.000
		Group II	1.945727 *	.000

Table 12. Vertical distance Y value –AB

		N	Mean	Std. Deviation
	Group I	11	2.44336	.874599
	Group II	11	2.60764	.545835
AB – Y				
	Group III	11	1.14327	.822884
	Total	33	2.06476	.993087

Table 13. Vertical distance Y value – AC

	Group I	11	12.70882	1.227628
	Group II	11	12.24864	.686417
AC – Y				
	Group III	11	9.07985	1.083841
	Total	33	11.34577	1.915494

Table 14.Vertical distance Y value – AD

	Group I	11	15.12555	.897716
	Group II	11	14.60136	1.158804
AD – Y				
	Group III	11	12.52191	1.224846
	Total	33	14.08294	1.563333

Table 15. Vertical distance Y value –AE

	Group I	11	14.19027	.881354
	Group II	11	14.14727	.652508
AE – Y				
	Group III	11	13.31582	1.363354
	Total	33	13.88445	1.060045

Table 16. Vertical distance Y value –AF

	Group I	11	8.25173	1.093525
	Group II	11	9.25873	.540568
AF – Y				
	Group III	11	7.44500	1.611429
	Total	33	8.31848	1.358003

Table 17. The combined mean and standard deviation of the vertical distances between and within the groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups R1 – Y	14.159	2	7.080	12.206	.000
Within Groups	17.400	30	.580		
Total	31.559	32			
Between Groups R12 – Y	85.882	2	42.941	40.858	.000
Within Groups	31.529	30	1.051		
Total	117.412	32			
Between Groups R3 – Y	41.719	2	20.859	17.150	.000
Within Groups	36.490	30	1.216		
Total	78.208	32			
Between Groups R4 – Y	5.345	2	2.673	2.619	.089
Within Groups	30.613	30	1.020		
Total	35.958	32			
Between Groups R5 – Y	18.166	2	9.083	6.671	.004
Within Groups	40.847	30	1.362		
Total	59.014	32			

Table 18. The significance level of the three groups by multiple comparisons between the groups for vertical distance: AB

Dependent Variable	(I) Sample Description	(J) Sample Description	Mean Difference (I-J)	Sig.
	Group I	Group II	-.164273	.869

AB - Y		Group III	1.300091 *	.001
	Group II	Group I	.164273	.869
		Group III	1.464364 *	.000
	Group III	Group I	-1.300091*	.001
		Group II	-1.464364*	.000

Table 19. The significance level of the three groups by multiple comparisons between the groups for vertical distance: AC

AC – Y	Group I	Group II	.460182	.550
		Group III	3.628973 *	.000
	Group II	Group I	-.460182	.550
		Group III	3.168791 *	.000
	Group III	Group I	-3.628973*	.000
		Group II	-3.168791*	.000

Table 20. The significance level of the three groups by multiple comparisons between the groups for vertical distance: AD

AD – Y	Group I	Group II	.524182	.513
		Group III	2.603636 *	.000
	Group II	Group I	-.524182	.513
		Group III	2.079455 *	.000
	Group III	Group I	-2.603636*	.000
		Group II	-2.079455*	.000

Table 21. The significance level of the three groups by multiple comparisons between the groups for vertical distance: AE

AE – Y	Group I	Group II Group III	.043000 .874455	.995 .122
	Group II	Group I Group III	-.043000 .831455	.995 .148
	Group III	Group I Group II	-.874455 -.831455	.122 .148

Table 22. The significance level of the three groups by multiple comparisons between the groups for vertical distance: AF

AF – Y	Group I	Group II Group III	-1.007000 .806727	.124 .052
	Group II	Group I Group III	1.007000 1.813727 *	.124 .003
	Group III	Group I Group II	-.806727 -1.813727*	.252 .003

Table 23. Third axis z value - AB

		N	Mean	Std. Deviation
AB - Z	Group I GroupII Group III Total	11	1.62491	.561848
		11	1.81391	.627474
		11	2.44891	1.159472
		33	1.96258	.877439

Table 24. Third axis z value – AC

AC – Z	Group I GroupII Group III Total	11	3.20873	.843715
		11	3.02182	.629878
		11	3.67164	.980353
		33	3.30073	.850717

Table 25. Third axis z value – AD

AD- Z	Group I GroupII Group III Total	11	3.34173	.665521
		11	2.75194	.656274
		11	4.13691	1.086816
		33	3.41019	.987025

Table 26. Third axis z value - AE

AE – Z	Group I GroupII Group III Total	11	-.38955	.826634
		11	-.37518	.732773
		11	-1.60918	.997379
		33	-.79130	1.018407

Table 27. Third axis z value - AF

AF – Z	Group I GroupII Group III Total	11	-.76618	.883846
		11	-.91600	.839494
		11	2.33782	1.129304
		33	.21855	1.783981

Table 28. The combined mean and standard deviation of the vertical distances between and within the groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups R1 - Z	4.099	2	2.050	2.994	.065
Within Groups	20.538	30	.685		
Total	24.637	32			
Between Groups R2 - Z	2.462	2	1.231	1.784	.185
Within Groups	20.697	30	.690		
Total	23.159	32			
Between Groups R3 - Z	10.627	2	5.314	7.758	.002
Within Groups	20.548	30	.685		
Total	31.175	32			
Between Groups R4 - Z	11.038	2	5.519	7.475	.002
Within Groups	22.150	30	.738		
Total	33.189	32			
Between Groups R5 - Z	74.230	2	37.115	40.324	.000
Within Groups	27.613	30	.920		
Total	101.843	32			

Table 29. The significance level of the three groups by multiple comparisons between the groups for third axis: AB

Dependent Variable	(I) Sample Description	(J) Sample Description	Mean Difference (I-J)	Std. Error	Sig.
		Group II	-.189000	.352804	.854

	Group I	Group III	-.824000	.352804	.066
AB - Z	Group II	Group I	.189000	.352804	.854
		Group III	-.635000	.352804	.187
	Group III	Group I	.824000	.352804	.066
		Group II	.635000	.352804	.187

Table 30. The significance level of the three groups by multiple comparisons between the groups for third axis: AC

	Group I	Group II	.186909	.354169	.858
		Group III	-.462909	.354169	.402
AC - Z	Group II	Group I	-.186909	.354169	.858
		Group III	-.649818	.354169	.176
	Group III	Group I	.462909	.354169	.402
		Group II	.649818	.354169	.176

Table 31. The significance level of the three groups by multiple comparisons between the groups for third axis: AD

AD – Z	Group I	Group II	.589791	.352891	.233
		Group III	-.795182	.352891	.078
	Group II	Group I	-.589791	.352891	.233
		Group III	-1.384973*	.352891	.001
	Group III	Group I	.795182	.352891	.078
		Group II	1.384973 *	.352891	.001

Table 32. The mean rank of the three groups by multiple comparisons between the groups for third axis: AE & AF

Sample Description		N	Mean Rank
AE – Z	Group I	11	19.50
	Group II	11	20.73
	Group III	11	10.77
	Total	33	
AF – Z	Group I	11	11.45
	Group II	11	11.73
	Group III	11	27.82
	Total	33	

Table 33. The significance of the three groups by multiple comparisons between the groups for third axis: AE & AF Test Statisticsa,b

	AE - Z	AF – Z
Chi-Square	6.938	20.681
Df	2	2
Asymp. Sig.	.031	.000

a. Kruskal Wallis Test

b. Grouping Variable: Sample Description

Table 34. Implant angulation in the z axis to the horizontal plane: A1

Angle		N	Mean	Std. Deviation
A1	Group I	11	89.87845	2.992399
	GroupII	11	88.18491	.811584
	Group III Total			

		11	86.38882	1.817392
		33	88.15073	2.475860

Table 35. Implant angulation in the z axis to the horizontal plane: A2

A2	Group I GroupII Group III Total	11	88.12855	1.306110
		11	88.48391	.853593
		11	85.71273	2.139879
		33	87.44173	1.937755

Table 36. Implant angulation in the z axis to the horizontal plane: A3

A3	Group I GroupII Group III Total	11	92.30218	1.581576
		11	92.02109	.726886
		11	93.21755	1.066513
		33	92.51361	1.253530

Table 37. Implant angulation in the z axis to the horizontal plane: A4

A4	Group I Group IIIGroup III Total	11	91.99255	1.317074
		11	92.09782	.965178
		11	92.46636	1.918340
		33	92.18558	1.423295

Table 38. Implant angulation in the z axis to the horizontal plane: A5

A5	Group I GroupII Group III Total	11	89.29973	2.912504
		11	88.57545	.927727
		11	85.97100	1.488475
		33	87.94873	2.391472

Table 39. Implant angulation in the z axis to the horizontal plane: A6

A6	Group I GroupII Group III Total	11	89.43773	3.296116
		11	88.71500	1.118309
		11	88.28655	3.452536
		33	88.81309	2.782745

Table 40. The combined mean and standard deviation of the implant angulations between and within the groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups A1	66.996	2	33.498	7.781	.002
Within Groups	129.160	30	4.305		
Total	196.156	32			
Between Groups A2	50.020	2	25.010	10.698	.000
Within Groups	70.136	30	2.338		
Total	120.157	32			
Between Groups A3	8.611	2	4.305	3.100	.060
Within Groups	41.672	30	1.389		
Total	50.283	32			
Between Groups A4	1.362	2	.681	.322	.727
Within Groups	63.463	30	2.115		
Total	64.825	32			
Between Groups A5	67.423	2	33.712	8.750	.001
Within Groups	115.589	30	3.853		
Total	183.012	32			

Between Groups A6	7.447	2	3.724	.465	.633
Within Groups	240.350	30	8.012		
Total	247.797	32			

Table 41. The significance level of the three groups by multiple comparisons between the groups for implant angulation: A1

Dependent Variable	(I) Sample Description	(J) Sample Description	Mean Difference (I-J)	Std. Error	Sig.
A1	Group I	Group II	1.693545	.884754	.152
		Group III	3.489636 *	.884754	.001
	Group II	Group I	-1.693545	.884754	.152
		Group III	1.796091	.884754	.022
	Group III	Group I	-3.489636*	.884754	.001
		Group II	-1.796091	.884754	.022

Table 42. The significance level of the three groups by multiple comparisons between the groups for implant angulation : A2

A2	Group I	Group II	-.355364	.651973	.850
		Group III	2.415818 *	.651973	.002
	Group II	Group I	.355364	.651973	.850
		Group III	2.771182 *	.651973	.001
	Group III	Group I	-2.415818*	.651973	.002
		Group II	-2.771182*	.651973	.001

Table 43. The significance level of the three groups by multiple comparisons between thegroups for implant angulation: A3

A3	Group I	Group II	.281091	.502551	.843
		Group III	-.915364	.502551	.180
	Group II	Group I	-.281091	.502551	.843
		Group III	-1.196455	.502551	.060
	Group III	Group I	.915364	.502551	.180
		Group III	1.196455	.502551	.060

Table 44. The significance level of the three groups by multiple comparisons between the groups for implant angulation : A4

A4	Group I	Group II	-.105273	.620180	.984
		Group III	-.473818	.620180	.728
	Group II	Group I	.105273	.620180	.984
		Group III	-.368545	.620180	.824
	Group III	Group I	.473818	.620180	.728
		Group II	.368545	.620180	.824

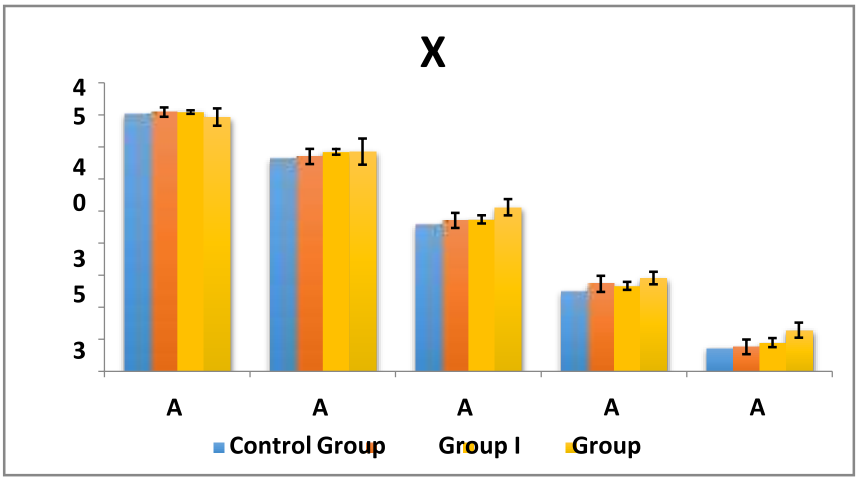
Table 45. The significance level of the three groups by multiple comparisons between the groups for implant angulation: A5

A5	Group I	Group II	.724273	.836983	.666
		Group III	3.328727 *	.836983	.001
	Group II	Group I	-.724273	.836983	.666
		Group III	2.604455 *	.836983	.011
	Group III	Group I	-3.328727*	.836983	.001
		Group II	-2.604455*	.836983	.011

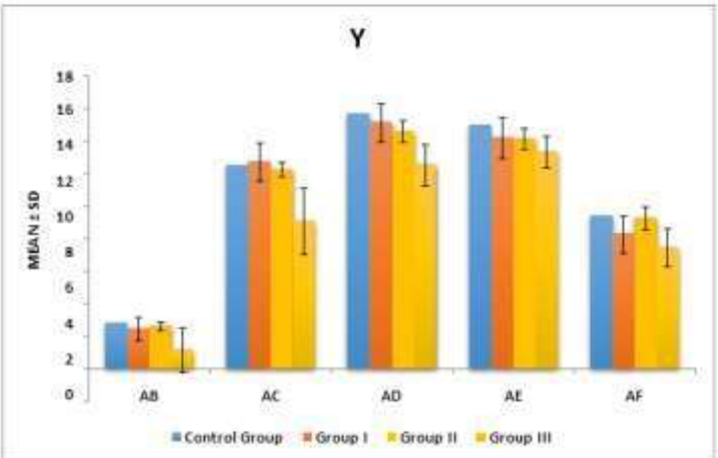
Table 46. The significance level of the three groups by multiple comparisons between the groups for implant angulation: A6

A6	Group I	Group II	.722727	1.206924	.822
		Group III	1.151182	1.206924	.611
	Group II	Group I	-.722727	1.206924	.822
		Group III	.428455	1.206924	.933
	Group III	Group I	-1.151182	1.206924	.611
		Group II	-.428455	1.206924	.933

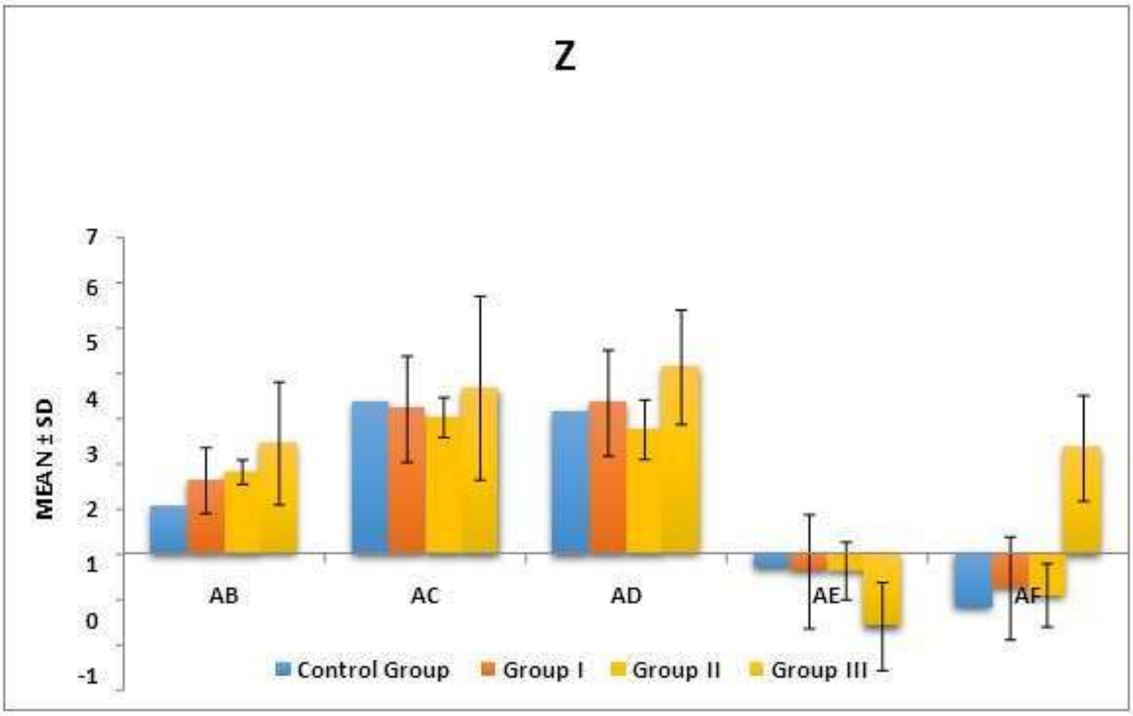
Graphs



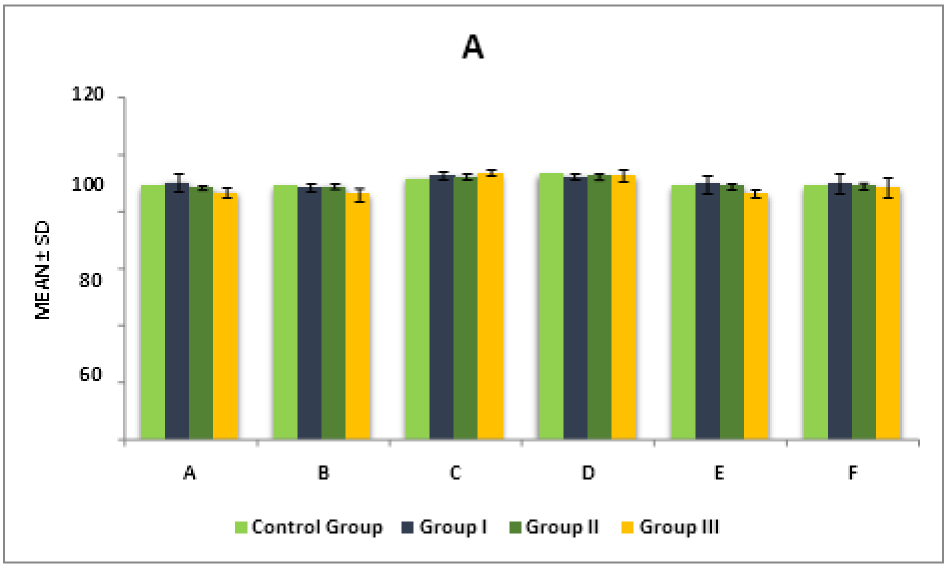
Graph 1. Representation of comparison of inter implant distance X-axis three groups along with control model



Graph 2. Graphical representation of comparison of inter implant distance Y axis of three groups along with control model



Graph 3. Graphical representation of comparison of third axis Z value of three groups with control model



Graph 4. Graphical representation of comparison of implant angulation to horizontal plane of three groups