COMPARATIVE EVALUATION OF ACCURACY OF CONVENTIONAL AND DIGITAL IMPRESSION TECHNIQUES FOR IMPLANTS PLACED WITH AND WITHOUT ANGULATION - AN IN-VITRO STUDY

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH I PROSTHODONTICS AND CROWN & BRIDGE

APRIL 2020

CERTIFICATE BY THE GUIDE

This is to certify that this dissertation entitled **"COMPARATIVE EVALUATION OF ACCURACY OF CONVENTIONAL AND DIGITAL IMPRESSION TECHNIQUES FOR IMPLANTS PLACED WITH AND WITHOUT ANGULATION - AN IN-VITRO STUDY"** ***is a bonafide research work done by*** **Dr. A. Gnanavel** ***under my guidance during his postgraduate study period between 2017- 2020.***

This Dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, *in partial fulfillment for the Degree of* **MASTER OF DENTAL SURGERY** *in* **PROSTHODONTICS AND CROWN & BRIDGE - BRANCH I.** *It has not been submitted partially or fully for the award of any other degree or diploma.*

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ACKNOWLEDGEMENT

This dissertation is the result of work with immense support from many people and it is pleasure now that I have the opportunity to express my gratitude to all of them.

I would like to convey my heartfelt gratitude and my sincere thanks to my Head of the department, Professor, **Dr. Shyam Mohan A, M.D.S., D.N.B.,** *Department of Prosthodontics and Crown & Bridge, for his exceptional guidance, tremendous encouragement, well-timed suggestions and heartfelt support throughout my postgraduate programme, which has never failed to drive the best out of me. I would like to profoundly thank him for giving an ultimate sculpt to this study. I will remember his help for life.*

I also express my deep sense of gratitude and my sincere thanks to my guide ***Dr.M.Aarti Rajambigai, MDS,*** *Professor for her guidance throughout.*

I also express my deep sense of gratitude and my sincere thanks to ***Dr.Ramesh Raja MDS****, Reader,* ***Dr. Joephin Soundar MDS****, Reader,* ***Dr.A.Niazahammed MDS****, Senior lecturer,* ***Dr.Sarathchandragovindraja MDS****, Senior lecturer for their timely assistance and help throughout the study.*

It is my extreme pleasure to extend my gratitude to my beloved chairman ***Dr. Jacob Raja*** *for his valuable support and constant encouragement throughout the period of my study.*

It gives me immense pleasure to convey my deep indebtness to our respected Principal, **Dr.Cynthia Sathiasekhar**, Administrative Director, **Dr. I Packiaraj**, Vice Principal (Academics), **Dr. J. Johnson Raja**, **Dr. Antony Selvi**, Vice Principal (Administration) and Members of the **Ethical Committee and Review Board** for the permission, help and guidance throughout the course.

I am grateful to my Mentors ***Dr. Sabarinathan. S***, ***Dr.*** **J. Johnson Raja**, ***Dr.Kamala Shankar*** *for their patient endurance, cooperation and support offered to me during my post-graduate course.*

I thank my senior colleagues ***Dr. S. Sakthi Prakash, Dr. Rinu Prathap, Dr.Selvin raj, Dr. Shyma Rose P.D*** *and my junior colleagues* ***Dr. G. Asweshya, Dr.K. Keerthiga, Dr. M. Mohamed Hajiral Beevi, Dr. M. Manimegalai, Dr.Sruneertha, Dr. Anumitha*** *for their kind help and constant support. My sincere thanks to all those help me directly and indirectly*

I once again thank ***Dr. S. Sakthi Prakash*** *for his immense support and help throughout.*

Last but not the least, even though words would'nt do much justice. I would like to specially thank my beloved wife ***Dr. Vidhya***, brother-in-law Dr. Ganesh for their unconditional love and support.

I am extensively thankful to my lovable son Bob@Adithya for his support and sacrifice throughout my studies. I am thankful to my beloved parents.

Above all I thank GOD almighty for all the grace endowed upon me.

Place: Name:

Date : Signature:

ABSTRACT

Background :

Impression making of multiple angulated implants needs precise technique to obtain perfection. Presently conventional techniques are found to be not fool proof with the advent of newer digital technologies in impression making probably we have a solution.

Aims and objectives :

To evaluate and compare the accuracy of closed tray, open tray and digital implant impression techniques of two parallel and non-parallel implants in an In-vitro study.

Materials and method:

Accuracy of impression techniques were evaluated in-vitro by means of placing two implants (4.2*10 mm, NORIS Medical Ltd, Israel) parallel to each other on the posterior region of partially edentulous mandibular wax model which was later polymerized to fabricate a PMMA model. On the contralateral side of the same model, mesially tilted implant was placed at an angulation of 17 degree to the other implant. Three Impression techniques such as open tray technique , closed tray technique, and digital impression technique were compared. Inter-implant distance were measured using Coordinate measuring machine. Measurements of various groups were tabulated and statistically analyzed using independent t-test and one way ANOVA.

Results:

Mean value of the inter-implant distance between parallel and non-parallel implants following three impression techniques were calculated separately. Mean value of inter-implant distance between parallel implants following closed tray (Group Ia), open tray (Group Ib), digital impression technique (Group Ic), were 14.523, 14.421, 14.276 respectively. Mean value of inter-implant distance between non-parallel implants following closed tray (Group IIa), open tray (Group IIb), digital impression technique (Group IIc) were 14.327, 14.415, 14.272 respectively. No significant difference existed between the control and test groups as revealed by independent t test. Statistical analysis of inter-group comparisons using one way ANOVA also showed no significant difference between the groups.

Conclusion:

Within the limitations of the study, no significant difference exist between the closed tray, open tray splinted and digital impression techniques of parallel implants depicting that the positional accuracy of the implants ,suggesting that these techniques can be employed in tilted implant scenario .But for non parallel implants open tray technique remains the ideal and digital impression technique is yet to match its level of accuracy.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF FIGURES

INTRODUCTION

Partial or complete edentulism is a major oral health concern in a large part of the adult population and there is a need for treating a sizeable percentage of such population with prosthodontic rehabilitation. Traditional treatments comprising of removable prostheses are often inadequate in restoring full masticatory function and can negatively affect nutrition, physical appearance, and self-esteem. Osseointegrated dental implants offer effective and definitive solutions for such a scenario. Dental Implants have become a milestone in dentistry and have changed the face of dentistry over the last three decades. Today implants are used to replace either single or multiple missing teeth apart from treating completely edentulous situations. Implants are in fact proposed as the first line of treatment for many conditions which earlier were treated with either removable or fixed, tooth or tissue supported prostheses. Innovations in the design, geometry and surface characteristics of dental implants were essentially introduced to widen the scope of implant therapy to a wide range of clinical situations such as complete edentulism, long and short span partial edentulism, missing a single tooth, maxillofacial prosthetics, etc. Advancements in material science, imaging systems and prosthetic technology have also led to a phenomenal change in the way implant treatment planning and execution are carried out. Increase in implant dentistry demanded more accurate recording of the three-dimensional position of the implants via impression and thus providing accurate final prosthesis for excellent rehabilitation.

Making a precise impression and thereby making the subsequent master cast for the implant is significant for the passive fitness of the final prosthesis. There are

several methods to achieve the passive fitness of the final prosthesis, though there is no distinct protocol been available yet. It is now believed that the impression materials are significantly improved, so selecting the proper technique would be the prime issue. Recent developments in impression techniques, to obtain the maximum accuracy of the implant position, has been regarded more than other issues. Some degrees of error and inaccuracies has also been noticed in the precise transfer of the implant positions for all impression methods. Dimensional changes occur due to the contraction in the impression material due to polymerization reaction with the formation of volatile materials and by-products and also from the pressure applied during the impression technique.

A dental impression of implants placed in the mouth form a critical aspect in final prosthesis and every effort should be made to ensure that the intraoral anatomy is accurately reproduced in the impression made.

Maximum precision in the transfer of clinical conditions to the dental laboratory is the utmost important factor in the fabrication of the final prosthesis. Therefore, one of the most critical steps for the fabrication of an efficient implant-supported prosthesis is an accurate transfer of the three-dimensional position of the implant from intra-oral condition to the master cast via impression. Inaccuracies and distortion in impression results in an inaccurate master cast, thus leading to the final prosthesis which is not relevant to the 3D position of the implant intra-orally. The resultant prosthesis can lead to potential biomechanical complications.[1]

Two main conventional implant impression techniques are open and closed tray impression technique. The direct or Open tray impression technique uses a custom or stock tray with access to the impression coping screws, which exposes the

coronal ends of the impression coping. The open tray technique can further be subdivided in to splinted and non-splinted techniques and the other impression technique is the indirect or closed tray impression technique, the copings are connected to the implant and after the removal of impressions, they are retained on the implants. These copings are then removed from the implant, attached to the implant analogs and reinserted in the impression.

Some authors insisted on the importance of splinting impression copings together intra-orally before making an impression. Materials used to splint impression copings include pattern resin, light-curing composite resin, impression plaster, and auto polymerizing acrylic resin. Splinting is done to eliminate the rotation of the impression copings while making an impression and also while fastening the analogs. But it is also reported that splinting may also result in deformation of impression material on removal in case of implants placed in a more buccal or labial inclinations.[2] The common material of choice for splinting is auto polymerizing resin and the present study uses pattern resin. The main drawback of auto polymerizing resin is polymerization shrinkage, but **Mojon et al**[3] stated that sectioning of acrylic resin splinting followed by resplinting resulted in 80% reduction of shrinkage.

Several impression materials have been used for multi-unit implant impression; the most commonly described were addition silicone and polyether impression materials. This can be co-related to their improved accuracy. The impression material used in the present study is polyvinyl siloxane (VPS). Polyvinyl siloxane is known for its high modulus of elasticity, excellent resistant to permanent deformation and better rigidity of putty. Polyvinyl siloxane as such is hydrophobic, hence in order to enhance the wettability, the manufacturers add extrinsic surfactants,

whereas polyether is hydrophilic in nature. **Lee et al**[4] and **cho et al**[5] claimed no significant differences in impression accuracy among polyether and polyvinyl siloxane impression materials. **Mahroo vojdani et al,**[6] **Enkling et al**[7] discussed one more new material vinyl siloxanether, composed of polyether and addition polyvinyl siloxane, a new impression material which shows excellent elastomeric properties and hydrophilic. The material attains high final hardness immediately after setting and shows excellent detailing of impression. However , Vinylsiloxanether is a relatively new material and there is limited literature evidence of the material and its properties.

There are few Variables that have been shown to influence implant impression accuracy that includes impression material selection, tray selection, impression approach, implant angulation and the inherent fit of impression components.

In several clinical scenarios it is not possible for parallel implant placement and angulated implants greatly influences the accuracy of implants.While numerous studies have evaluated and compared existing implant impression techniques, research up to date does not support any single impression technique as superior to allothers.[1]

The development of digital dental impression systems has enhanced patient care and has provided a paradigm shift in treatment. With 3D visualization of the intraoral condition as well as the designed prosthesis, dental treatment has become more predictable and precise. The advent of intraoral scanners (IOSs) has led to a valuable change in implant dentistry. Though the first Intra Oral Scanner was commercially available two decades ago, it has achieved immense popularity in recent years. The digital impression has gained high patient acceptance, reduce possible errors of impression making and master casts, reduces chairside time, provides a three-dimensional image of the preparation[8] and ease of communication between the

clinician and the laboratory . Many pieces of literature discuss and support various impression techniques and impression materials in the field of implant impression and our study is designed to focus on the precision of conventional and digital impression techniques using 3 different techniques viz closed ,open and digital in parallel and nonparallel implants.

The null hypothesis is that there is no difference in the accuracy of different types of impression techniques in parallel and nonparallel implants.

AIMS AND OBJECTIVES

Aim

The aim of this in vitro study is to evaluate and compare the accuracy of conventional and digital impression techniques for implants placed with and without angulation.

Objectives

1. To evaluate the accuracy of closed tray impression technique for two parallel and non parallel implants.
2. To evaluate the accuracy of open tray impression technique for two parallel and non parallel implants.
3. To evaluate the accuracy of digital impression technique for two parallel and non parallel implants.
4. To compare the accuracy of closed tray, open tray and digital impression techniques for parallel and non parallel implants

REVIEW OF LITERATURE

Impression techniques:

Enas A Elsehenawy et al[9] and **Tsagkalidi et al[10]** an in vitro study with three reference models in which implants were placed t parallel , 15 degree and 30 degree angulations and the three impression techniques were used , indirect impression technique, direct unsplinted impression technique and direct acrylic resin splinted impression techniques and poured with type IV dental stone. The sample size was 10 per group.The study reported that upto 15º angulation of implants irrespective of splinting the direct impression technique is superior to indirect impression technique, when the angulation increases to 30º the direct acrylic resin splinting technique is more accurate than the unsplinted one and the angulation significantly affected the indirect impression technique. Studies by **Lee et al[4]** and **carr et al[11]** also supported the same.

Sevcan kurtulmus yilmaz et al[12], An in vitro study with three master models simulating partially edentulous mandible with parallel implant placed at second premolar region and implants that are placed at parallel, 10 degree 20 degree angulations at second molar region. The study employs splinted direct and indirect impression technique using polyether, poly vinyl siloxane and vinyl polyether silicone impression materials. 180 impressions were made. He claimed that the direct splinted impression technique showed greater accuracy than the indirect impression techniques in both parallel and non parallel implants.

According to **Hatim N et al[13]** and **Wostmann B et al[14]**, open tray impression technique showed better results with the closed tray impression technique showing some amount of distortion related to the transfer of copings and open tray technique

showed lesser axis rotations.

Arpita tandon et al[15], conducted an in vitro study in which a total of 60 impressions were made with polyether and polyvinyl siloxane impression material using closed and open tray technique and the casts were evaluated in a co-ordinate measuring machine. The study reported no significant statistical difference among the impression techniques and impression materials used, hence the study supported both the impression techniques and both the impression materials. This study used four parallel implants. Unpaired t test is used for the comparison.

According to **Prithiviraj et al**[16] based on a review of different implant impression materials and techniques stated that, when the implant numbers are ≥4, several studies supported pick up impression technique and also reported superior accuracy of impressions with open tray splinted impression technique and supporeted both poly vinyl siloxane and polyether impression material as the material of choice for making implant impressions.

An in vitro study on two implant level impression techniques, direct splinted and non splinted impression technique by **Choi et al**[17] evaluating the accuracy of the same for the fabrication of multi unit implant prosthesis claims both the techniques showed almost similar reproduction of implant position in cases of parallel implants and implants with 8º angulation. He reported that implants with ≤8 degree angulation allows for easy removal of the splinted or non splinted impressions. The results of the study showed no statistically significant deformation differences between direct non splinted and splinted impression technique $p>0.05$

A literature review done by **Mirza rustum baig**[18] on multi unit implant accuracy claims that many studies supported auto polymerizing resin as splinting

material of choice. One study by **Del aqua et al**[19] used metal splinting and self cure acrylic resin splinting in a completely edentulous situation with four implants placed and reported that metal splinting was superior.

Abolfazl saboury et al[20], assessed the accuracy of the implant impression by measuring the vertical gap between the prosthetic superstructure and the underlying implant abutment with two 15 degree mesially angulated implants placed at the definitive casts and impressions were made. Four impression techniques were evaluated. The study demonstrated that the rigid metal splinted impression coping and the custom made acrylic resin transfer cap impression techniques resulted in significantly more accurate impressions in comparison to the snap fit and non splinted open tray impression technique. The mean values were compared using ANOVA and post hoc tests.

A systematic review by **Heeje Lee et al**[4] on accuracy of the implant impression reported that the more recent literature reviews supported the splinting of impression copings for more accurate transfer of implant position to the impression. Acrylic resin is the material of choice for many authors. In order to minimize the errors due to polymerization shrinkage many authors like **Assif et al**[21]**, Inturregui et al**[22] sectioned the splint and then resplinted. Studies conducted by **Vigolo et al**[23], **Naconecy et al**[24]**, Assuncao et al**[25]**, Cabral et al**[26] all supported the splinting impression techniques thus minimizing the distortion and for greater accuracy of transfer of implant position to the impression.

Daoudi et al[27] conducted a study in which he included the senior dentists, post graduate dental students and dental technicians and made them to reposition the copings after the transfer impression making and the study results stated that none of

the copings were repositioned properly to its original position. Hence he concluded that this error will be magnified in situations where multiple implants were placed. Therefore , several authors supported pick up impression technique to transfer impression especially in case of multiple implants.

Aman arora et al[28], done a study to compare the accuracy of the casts obtained from parallel and angulated implants with splinted and non splinted impression technique. The study used two edentulous maxillary stainless steel model with 7 implant analogs placed parallel to each other in one model and angulated on the other. 40 impressions made in each model using open tray impression technique with polyether impression material. The study results showed that splinting resist the translation and rotation of the impression copings hence improve the impression accuracies. One way ANOVA, bonferroni test, post hoc, and unpaired t test were done for statistical analysis. The above study was well supported by the study conducted by **Assif et al**[21], and **Tarib et al**[29].

Lee et al[4] stated that splinting of impression copings in open tray impression technique doesn't make any differences in determining the accuracy of the impression. His study involved two implants in master model placed at 10 degree divergence angle

Inturregui et al[25] also preferred non splinted open tray impression technique.

Jason burns et al[30] stated that the custom trays produced impressions with greater accuracy than the stock trays. He used polycarbonate stock impression trays and rigid custom made impression trays made using single sheet of rigid visible light polymerizing custom tray material. He reported that the flexible stock trays were more inaccurate and also his study resulted in 10μm difference in median between the

stock and custom impression trays measuring the vertical fit discrepancies which is statistically significant.

Implant angulation

Several authors reported that as the angulation of the implant increases the accuracy of the impression decreases. Implant impression accuracy has also been shown to be inversely affected by the number of the implants, and this was thought to be due to increased distortion and deformation on removal of the impression.

Parameshwari et al[31] conducted an in vitro study assessing the accuracy of stock metal tray, closed custom tray and open non splinted custom tray impression techniques using poly vinyl siloxane and polyether impression materials in recording implants with angulations (0º, 15º, 25º) and the obtained casts were analysed in coordinated measuring microscope. The study claimed that the stock tray impression technique showed increased mean linear distortion than that of the custom tray impression technique. Similarly poly vinyl siloxane impressions that are obtained using closed custom tray technique showed statistically significant difference ($p<0.01$) in terms of accuracy compared to polyether. The study also stated that the accuracy of open and closed tray impression technique remains comparable, with the open tray technique showing better results in cases of multiple implants and implants placed with the angulations of more than 20 degrees.

According to **Zerrin fidan akalin et al**[2] an in vitro study on the effects of implant angulation, impression material, he included the new variable the arch curvature width and their impacts on implant transfer model. From the model where three implant analogs placed in canine, first premolar and first molar region with 10º buccal angulation. The study stated that increase in implant angulation resulted in

increase in impression distortion in transfer model especially in multiple implants. Regarding the arch curvature width, the study claims that it doesn't make any differences in accuracy of transfer models.

Jemt and Lie[32] claimed that the distortion of impression is directly proportional to the arch curvature width.The studyanalysed the passive fit of the implant superstructures that are fabricated on six implants.

According to **Conard et al**[33], angulations upto 15º, the accuracy of both direct and indirect impression techniques remain unaffected and Carr also supported the same.

Whereas when the angulation of the implant is greater than 20 degree, it negatively affected the impression accuracy. **Howell et al**[34] reported that when the implant angulation is 30º open unsplinted custom tray impression technique showed better results than the closed custom tray impression technique.

According to **Conrad et al**[33] and **Lee et al**[4] , in some situations, the indirect closed tray impression technique is preferred to direct open tray impression techniques, such as in cases of gagging, limited inter -arch space and in cases where access to the posterior region is limited.

Impression material

Carr AB[11] in 1992 concluded that there is an inevitable, inherent discrepancy in the implant impression, which was quoted in the range of 50 μm. One of the factors related to this discrepancy is the shrinkage and contraction of the impression material due to the cross- linking and rear arrangement of the polymer chains. Further shrinkage can occur due to loss of volatile constituents and by-products. The expansion will also occur if there is water sorption.

Mahroo vojdani et al[6], conducted a study on accuracy of impression material using polyether, poly vinyl siloxane and vinyl siloxanether in parallel and non parallel implants ,where the non parallel implants were placed at 30º buccal inclination and 20º in either mesial or distal inclination. The study concluded that all the three impression materials showed comparatively better results in case of parallel implants whereas, poly vinyl siloxane showed superior results in case of non parallel implants.

Lee et al[4] stated that the combination of putty and light body poly vinyl siloxane showed more accuracy than medium body polyether in case of sub gingivally placed implants and also suggested that providing an extension of 4mm to the original impression coping compensates for the inaccuracies encountered in subgingivally placed implants.

According to **Sorrentino et al[35]**, poly vinyl siloxane impression material showed more accuracy than polyether impression material.

Sevcan kurtulmus yilmaz et al[12] claimed that poly vinyl siloxane impression material showed more accuracy in case of 10º and 20º angulation of implants by digitally evaluating the impressions made in the master model using polyvinyl siloxne, polyether and vinyl polyether siloxane impression material. The master model and the casts are scanned using modified laser scanner and the datas transferred using VRMesh software . According to his study, impressions with polyether and poly vinyl siloxane showed no significant differences for parallel implants, whereas poly vinyl siloxane and recorded superior results for 10º and 20º angulated implants which is attributed to the high elastic recovery of poly vinyl siloxane impression material.

Digital impression:

According to **Ender et al**[36], digital impression when taken with the proper scanning technique, they provide good clinical results.

Papaspyridakos et al[37], on an in vitro study comparing the accuracy of digital and conventional implant impression on five implant in an edentulous mandible using TRIOS intra oral scanner, says digital impressions are as accurate as the conventional impressions.

Emir yuzbasioglu et al[38] carried out a clinical trial with twenty four subjects involving twelve males and twelve females who had not experienced conventional and digital impression procedures. A standardized questionnaire was made to record the subject's attitude, preference and perception towards the digital and conventional impression procedures. The study reported that the subjects accepted and preferred digital impression over the conventional impression mainly because of the comfort.

Kinga Basaki et al[1] conducted a study using a mandibular reference model with the implant placed in the first premolar and the molar position in a posterior bilateral edentulous scenario, where implants were placed parallel on right side and in the left side were placed at 10 and 30 degrees with the convergence angle of 20 degrees. Digital impressions were made with the intra oral scanner and the open tray impression technique was carried out with the poly vinyl siloxane impression material. Quality control software and laser scanners were used. The above study demonstrated that the casts obtained from digital impression technique were significantly less accurate than the conventional impression technique. Casts showing errors of less than 60µm in implant position was considered acceptable. The conventional impression technique demonstrated an average 56µm, whereas the three

dimensional errors shown by the digital impression technique was an average of 116µm which seems to be very significant. The study also claimed that the implant angulation is not said to influence the accuracy of the casts obtained from digital and conventional impression techniques.

Gypsum models and milled models

An in vitro study evaluating the accuracy of implant impression by digital and conventional impression techniques by **Sang Lee et al**[39], using thirty gypsum models and thirty digital models from a reference model obtained using conventional and digital impression technique respectively, that are scanned using laboratory scanner. The results obtained stated that there is no statistically significant difference in terms of accuracy among the gypsum models and the digitally milled models, except in the areas of anatomical fossae, grooveswhere gypsum models showed more accuracy, however they showed differences in terms of vertical position of the implants. Vertical position of the implant is more apical in gypsum model and it is coronal in digital milled cast as compared to their respective master models. The discrepancies are more attributed to the processing errors than scanning errors. Thus the study concluded that the gypsum models are comparable to that of the digitally milled models.

MATERIALS AND METHODS

The following materials, instruments and equipments were used for the study:

Materials used

1. Root form endosteal implants, 4.2*10mm (NORIS Medical Ltd, Israel)
2. Open tray transfer (NORIS Medical Ltd, Israel)
3. Closed tray transfer (NORIS Medical Ltd, Israel)
4. Healing abutments for digital impression, (NORIS Medical Ltd, Israel)
5. Implant analogs, (NORIS Medical Ltd, Israel)
6. Polyvinylsiloxane (putty & light body)– Flexceed (GC corp , USA)
7. Pattern resin (GC corp USA)
8. Heat polymerizing acrylic resin (DPI India)
9. Auto polymerizing acrylic resin (DPI India)
10. Type 4 dental stone (Kalabhai Kalrock)
11. Modelling wax (DPI ,India)
12. Photo-active resin (ANYCUBIC, 3D Printing UV Sensitive Resin)

Equipments and Instruments used

1. Intra oral scanner, Medit i500
2. Coordinate measuring machine, TESA MICRO-HITE 3D
3. 3D printer, ANYCUBIC photon UV LCD 3D printer
4. Surveyor
5. Implant placement guide (proarch guide , Straumann)
6. Abutment hex driver (NORIS Medical Ltd, Israel)

Methodology

1.Fabrication of master reference model

a.Fabrication of wax model:

A mandibular dentulous silicone laboratory mold was taken and filled with molten modeling wax and allowed to cool. After cooling , the wax model was retrieved from the mold. Second premolar , first and second molar teeth in the mold were removed and residual ridges shaped so as to create a bilateral tooth bound saddle edentulous situation . The wax model thus obtained was further allowed to harden by keeping in the refrigerator.

b.Implant placement in wax model

The hardened wax model was placed on the surveying platform of a surveyor. The points for implant placement were demarcated using a divider, so as to maintain an inter implant distance of 12mm and implant to tooth distance of 6mm on either sides.

The demarcated sites were softened with the hot wax spatula and implants were placed into the molten wax at the sites with the help of a surveyor.

In one side the two implants were placed parallel to each other, whereas on the other side, implant was placed mesially at an angulation of 17º to the distal implant.

c.Conversion of wax model into PMMA model

Closed tray impression copings were connected to the implants placed in the wax model to help retaining the implant position while dewaxing procedure. The wax

model with the implant connected to the closed tray copings were flasked, dewaxed and processed with the heat cure poly methyl methacrylate using the long curing cycle, 74ºc for eight hours and 100ºc for one hour . The acrylic model was retrieved after deflasking and finished and polished.

Grouping

Samples are grouped as following:-

Group I - Parallel Implant (Ia- Closed tray(10nos), Ib- Open Tray(10nos), Ic- Digital(10nos))

Group II - Non- Parallel Implant (IIa- Closed tray(10nos), IIb- Open Tray(10nos), IIc- Digital(10nos))

Making of closed tray impression

Closed tray impression copings 8mm in height were connected to the implants on both the sides and hand tightened. A stock metal tray was chosen and tray adhesive was applied. A single stop putty- light body wash impression was made using (addition) polyvinyl siloxane impression material. After the impression was set, the tray was removed from the model and the closed tray copings were removed and connected to the implant analogs and manually replaced into the impression.

Making of open tray impression

Open tray impression copings 8mm in height were connected to the implants on both the sides and hand tightened. These open tray copings were splinted with pattern resin on both the sides. They were sectioned and re-splinted to compensate

polymerization shrinkage. A custom tray was fabricated using auto polymerizing acrylic resin. An opening was made on both sides at the implant site for holding the open tray impression copings and tray adhesive was applied. A single stop putty- light body wash impression was made using (addition) polyvinyl siloxane. After the impression was set, the impression tray was removed from the model and the open tray copings were removed along with the impression tray. Analogs were connected to the open tray copings for making a stone cast.

Fabrication of stone cast

Both the closed and open tray impressions (n=10 for each group) were poured in type 1V dental stone, kalabhai kalrock and allowed to set. The casts were retrieved from impressions carefully and then the impression copings were removed .

Making of digital impression

Healing abutments of 3mm in diameter, 5 mm in length were placed on all four implants in the master acrylic model. The model was then scanned digitally using the intra oral scanner, medit i500. According to the manufacturer recommendations ,the process was repeated upto ten times. The data obtained was stored and numbered. 3D printed models of the scanned data was obtained by connecting the scanned data to the STL file and feeding them into the 3D printer, ANYCUBIC photon UV LCD 3D printer A photo active resin , was used to obtain the 3D printed model.

Measurement of positional accuracy

All the test samples were subjected to measurement of positional accuracy using a co-ordinate measuring machine(CMM). An industrial three-dimensional

CMM was used to measure the master model in order to obtain the actual truth data of the three-dimensional position of the implants. The accuracy of the CMM was certified by the National Entity of Accreditation with a maximum permissible error for length measurement of (1.9 + 3 L/1000 μm) according to ISO 10360-2, geometrical product specifications. A high-accuracy touch signal probe with 1 mm ruby sphere was used to measure the points of the center of healing analogs to locate them in the *x*, *y*, *z*-axis of the space. Also, the circumference of the healing analog was measured to determine the center. This procedure was repeated for ten times in master model. A mean of the ten measurements performed with the CMM was used as the final location of the implants. In the present study, the inter implant distance along the horizontal axis (X axis) was considered as a measure of positional accuracy.

The data obtained for each sample was grouped, tabulated and subjected to statistical analysis using (SPSS software 26.00) and Independent t test and ANOVA were preformed.

METHODOLOGY FLOW CHART:

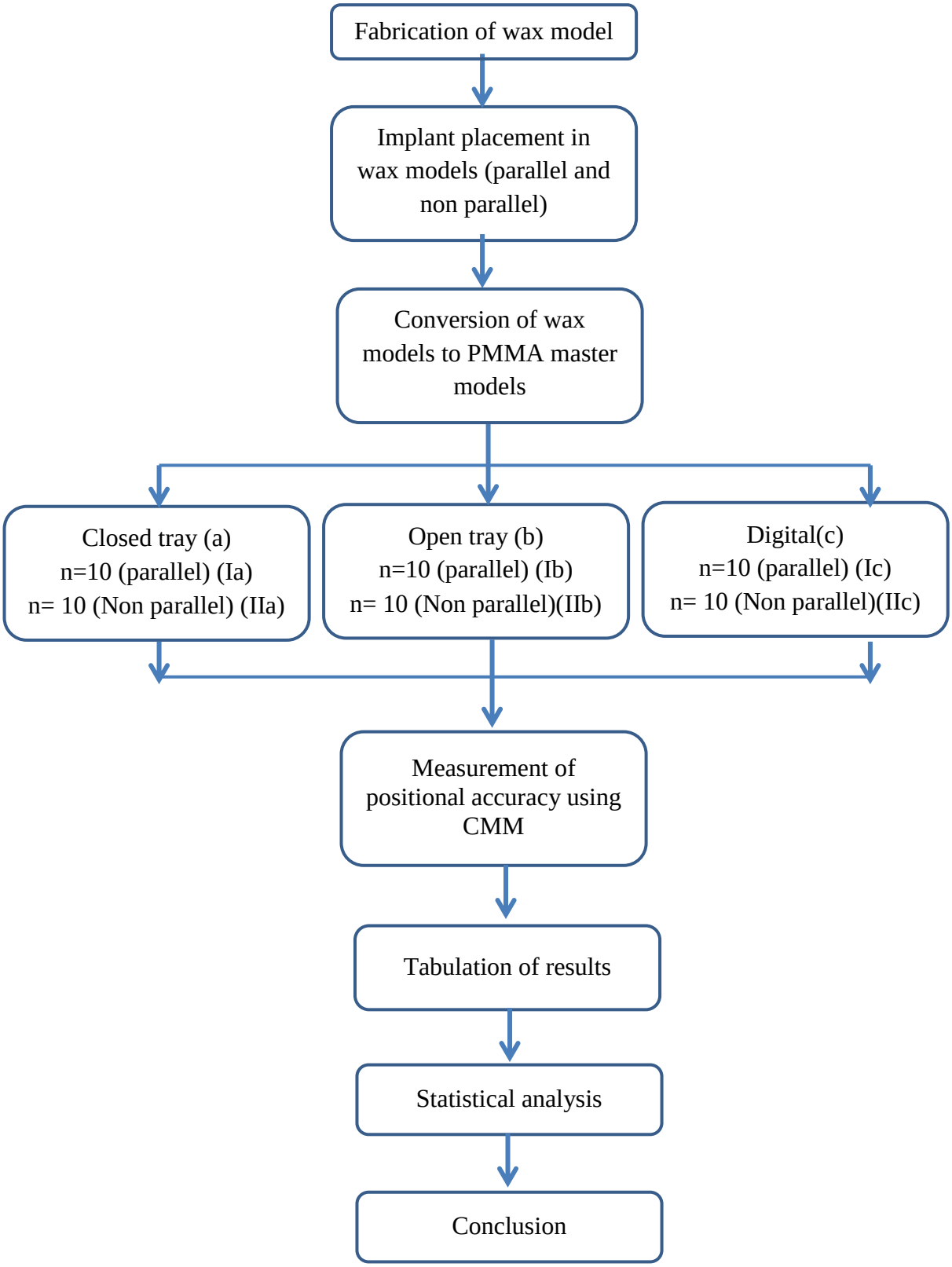


FIGURE 1: CO ORDINATE MEASURING MACHINE

FIGURE 2 : INTRA ORAL SCANNER

FIGURE 3: NORRIS IMPLANTS, 4.2*10MM

FIGURE 4: IMPLANT PLACEMENT GUIDE

FIGURE 5: POLYVINYLSILOXANE (PUTTY & LIGHT BODY)

FIGURE 6: PATTERN RESIN

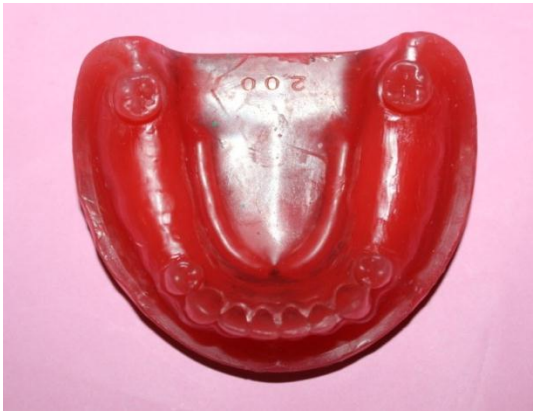


FIGURE 7: WAX MODEL

FIGURE 8: MASTER MODEL

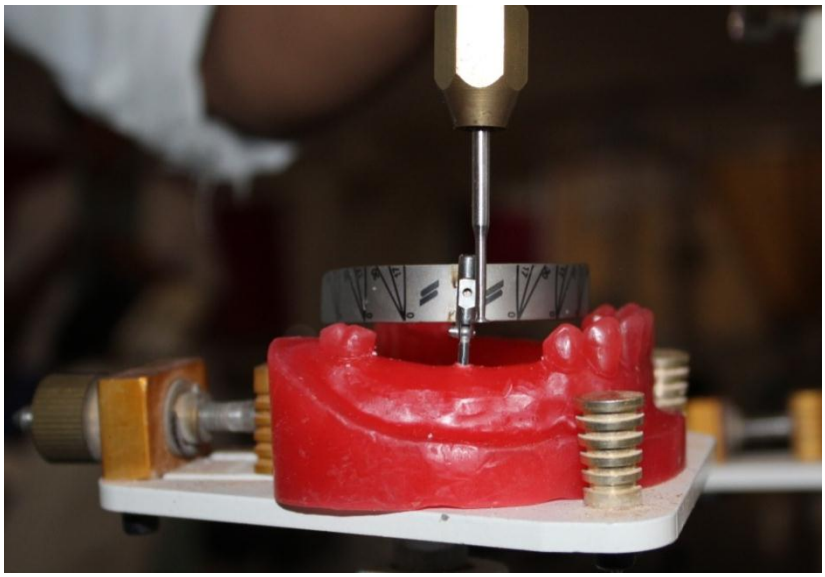


FIGURE 9: WAX MODEL WITH ANGULATION GUIDE

FIGURE 10: CLOSED TRAY IMRESSION MAKING

FIGURE 11: SPLINTING WITH PATTERN RESIN

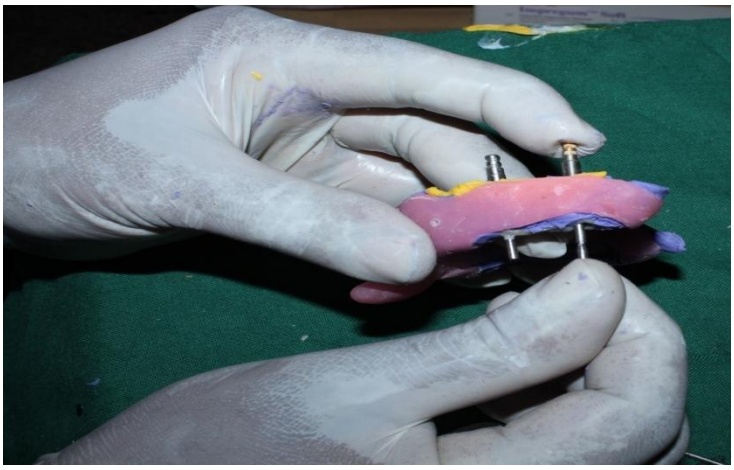


FIGURE 12: OPEN TRAY IMRESSION MAKING

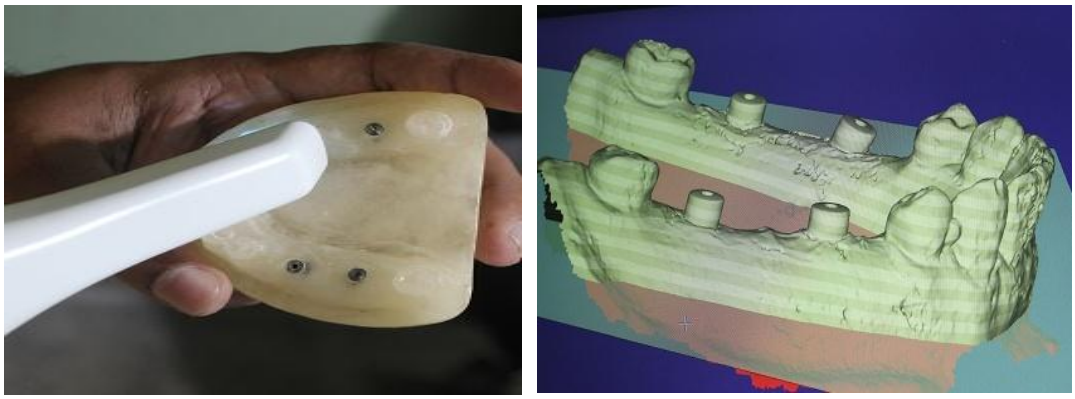


FIGURE 13: DIGITAL IMRESSION MAKING

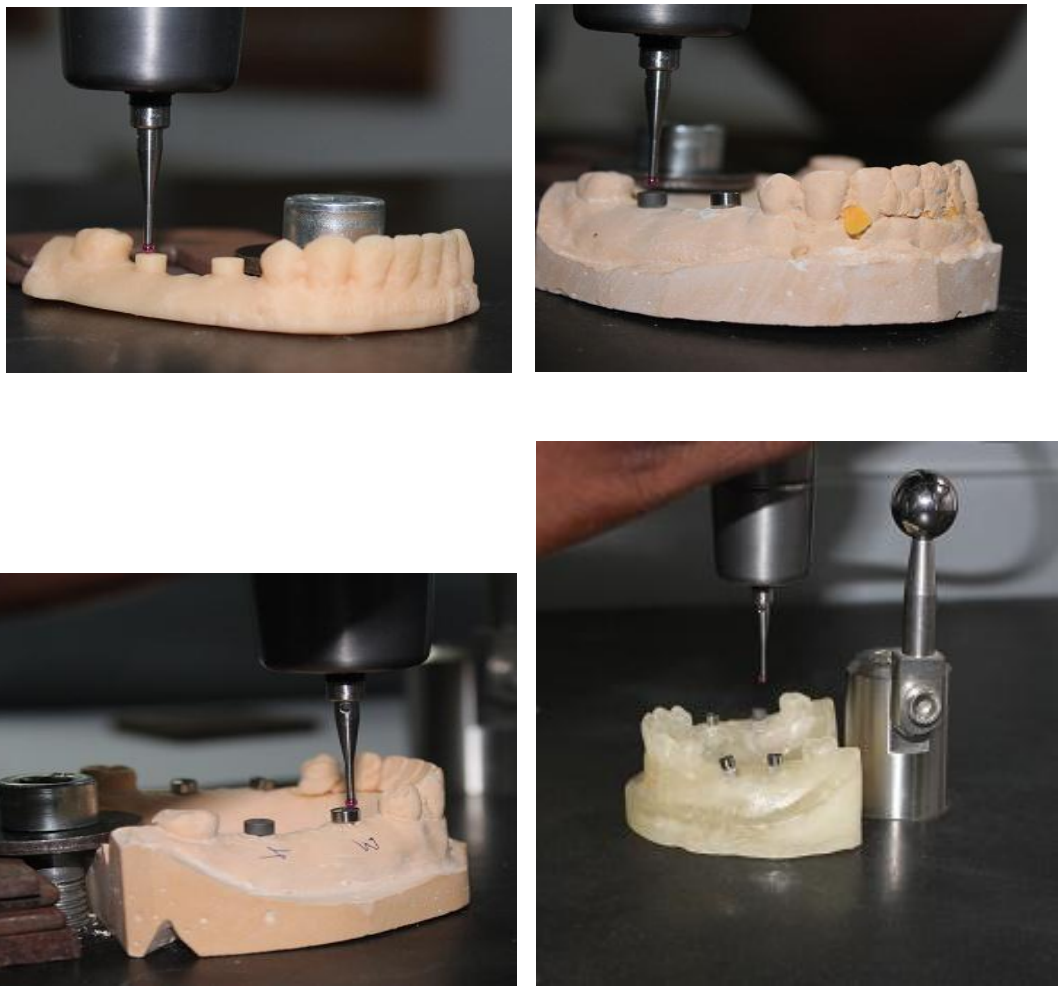


FIGURE 14: MEASUREMENT FROM CO ORDINATE MEASURING MACHINE

RESULTS

The data obtained was tabulated and statistically analysed.

The inter implant distance of parallel implants measured using closed tray impression , open tray impression and digital impression technique is compared with that of the control group and subjected to independent t test with the values being insignificant , p value of 0.184, 0.415 and 0.950 respectively, as expressed in Table 1,3,5.

Similarly the inter implant distance of non-parallel implants using closed tray impression , open tray impression and digital impression technique is compared with that of the control group and subjected to independent t test with the values being insignificant, p value of 0.162, 0.371 and 0.079 respectively , as expressed in Table 2,4,6.

Inter group (Group Ia, Ib, Ic) comparison is done using ONE WAY ANOVA. Comparison among the groups in case of parallel implants shows insignificant results with the p value of 0.213.(Table 7)

Similarly, Inter group (Group IIb, IIb, IIc) comparison done using ONE WAY ANOVA among the non parallel implants also is statistically insignificant with the p value of 0.495(Table 8)

Comparison of inter implant distance of parallel implants obtained using closed tray with that of the control

Table 1: Independent t test of comparison of parallel implants using close tray with control.

Impression	N	Mean	SD	SE	Independent t test	p value*
Control	10	14.264	0.520	0.164	1.38	0.184
Closed tray	10	14.523	14.858	14.523		

*p<0.05 is considered to be statistically significant.

Comparison of inter implant distance of non parallel implants obtained using closed tray with that of the control

Table 2: Independent t test of comparison of non parallel implants using close tray with control.

Impression	N	Mean	SD	SE	Independent t test	p value*
Control	10	14.575	0.462	0.146	1.459	0.162
Closed tray	10	14.327	0.275	0.087		

*p<0.05 is considered to be statistically significant.

Comparison of inter implant distance of parallel implants obtained using open tray with that of the control

Table 3: Independent t test of comparison of parallel implants using open tray with control.

Impression	**N**	**Mean**	**SD**	**SE**	**Independent t test**	**p value**
Control	10	14.264	0.520	0.164	0.834	0.415
Open	10	14.421	0.289	0.092		

*p<0.05 is considered to be statistically significant.

Comparison of inter implant distance of non parallel implants obtained using open tray with that of the control

Table 4: Independent t test of comparison of non parallel implants using open tray with control.

Impression	N	Mean	SD	SE	Independent t test	p value*
Control	10	14.575	0.462	0.146	0.918	0.371
Open tray	10	14.415	0.300	0.095		

*p<0.05 is considered to be statistically significant.

Comparison of inter implant distance of parallel implants obtained using digital impression technique with that of the control

Table 5: Independent t test of comparison of parallel implants using digital impression with control.

Impression	N	Mean	SD	SE	Independent t test	p value
Control	10	14.264	0.520	0.164	0.063	0.950
Digital	10	14.276	0.340	0.108		

*p<0.05 is considered to be statistically significant.

Comparison of inter implant distance of non parallel implants obtained using digital impression technique with that of the control.

Table 6: Independent t test of comparison of non parallel implants using digital impression with control.

Impression	N	Mean	SD	SE	Independent t test	p value*
Control	10	14.575	0.462	0.146	1.863	0.079
Digital	10	14.272	0.228	0.072		

*p<0.05 is considered to be statistically significant.

Comparison of inter implant distance of parallel implants among closed tray, open tray and digital impression technique. ANOVA

Table 7: Inter Group comparison of parallel implants using ONE WAY-ANOVA

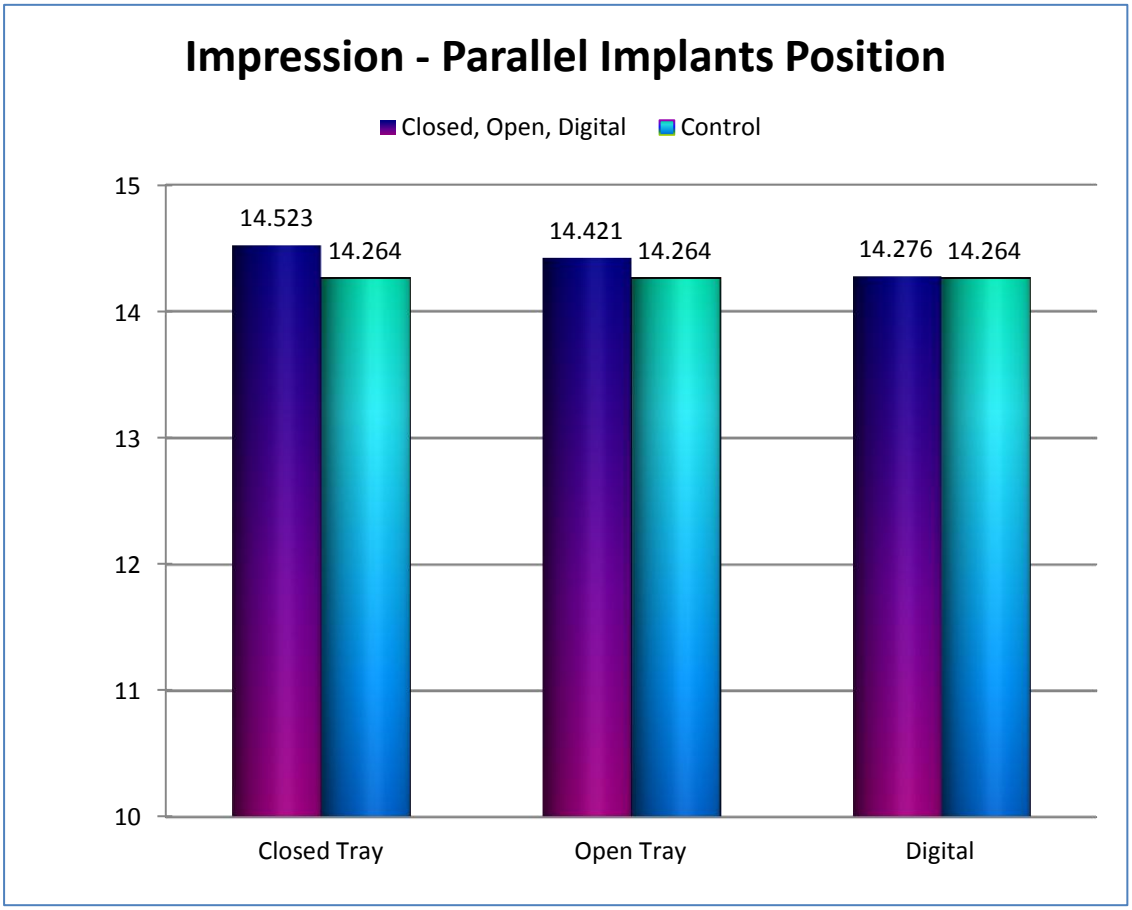
Group	N	Mean	SD	SE	ANOVA	P
Closed Tray	10	14.523	0.287	0.091	1.64	0.213
Open Tray	10	14.421	0.289	0.092		
Digital	10	14.276	0.340	0.108		
Total	30	14.407	0.313	0.057		

Comparison of inter implant distance of non parallel implants among closed tray, open tray and digital impression technique. ANOVA

Table 8: Inter Group comparison of non parallel implants using ONE WAY-ANOVA

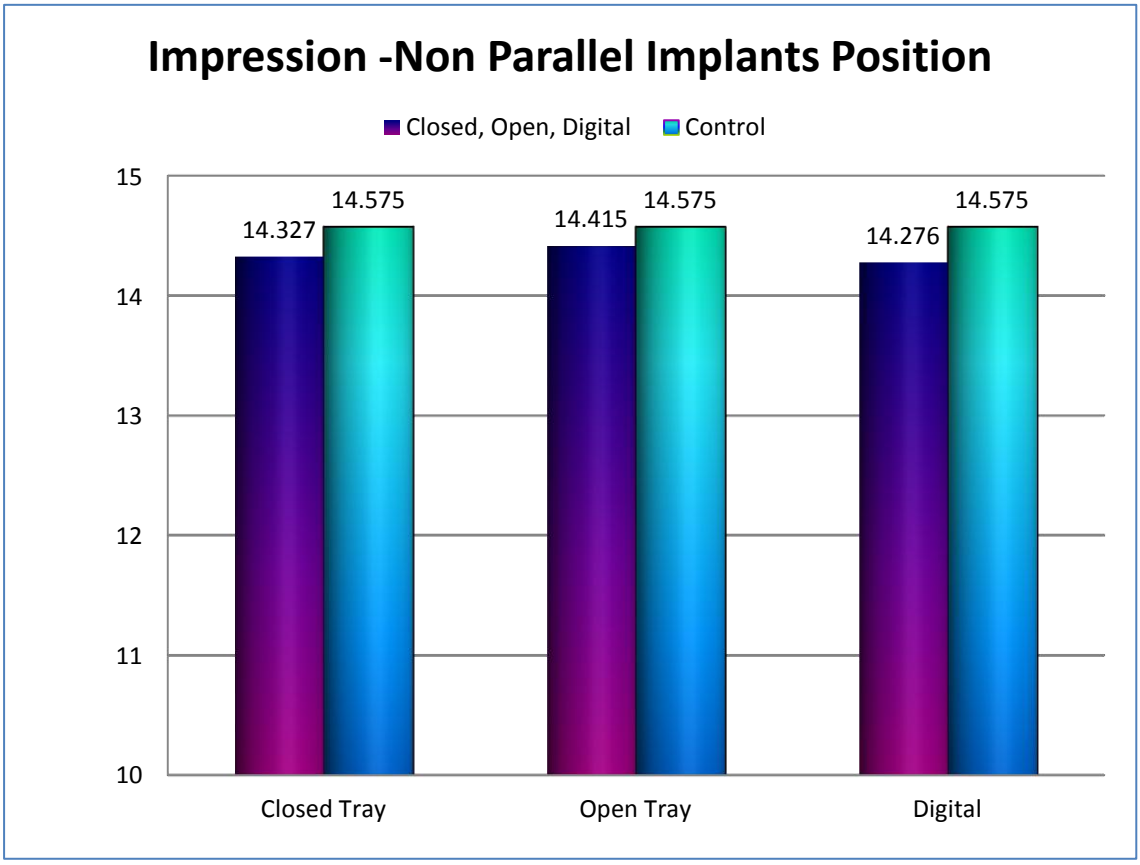
Group	N	Mean	SD	SE	ANOVA	P
Closed Tray	10	14.327	0.275	0.087	0.722	0.495
Open Tray	10	14.415	0.300	0.095		
Digital	10	14.272	0.228	0.072		
Total	30	14.338	0.267	0.049		

Diagram 1: Bar diagram indicating comparison of three of groups in parallel implants



Control group mean:14.264

Diagram 2: Bar diagram indicating comparison of three of groups in non parallel implants



Control group mean: 14.575

DISCUSSION

The present study was aimed at evaluating the accuracy of conventional and digital impression techniques for implants placed with and without angulation.

Implant impressions aim to duplicate the three dimensional position of implants in a working cast as it is in the patient's mouth. Such impressions can be made either at implant level or abutment level depending upon the type of prosthesis , need for customising the prosthetic superstructure ,clinician's prerogative etc., In partially edentulous situations , implant level impressions are preferred than abutment level impressions for a variety of reasons such as ability to cast and mill customized abutments and provision of screw retained prosthesis,etc.

The choice of close tray or open tray implant level impression techniques depends upon the number , depth, angulation, relative parallelism of the implants etc., With the advent of digital impressions using intra oral scanning devices , the accuracy of conventional and digital impressions have been studied by many authors with varying results.

Rationale for measuring the accuracy of various impression techniques of angulated implants, in addition to parallel implants, is that some clinical situations necessitate non parallel placement of implants to avoid surgical complications such as mandibular nerve displacement, maxillary sinus wall perforation. Moreover, angulated implants cause difficulty while making impression. Scientific evaluation is mandatory to find out the best available impression technique.

Various impression techniques employed in our study are closed tray impression technique, open tray splinted impression technique and digital impression

technique.

The material of choice for making impressions following closed tray and open tray impression technique is polyvinyl siloxane impression material. Polyvinyl siloxane impression material is selected because of its superior dimensional accuracy, less distortion and better elasticity in contrast to the rigid nature of polyether. Polyether cannot be used in areas with severe undercuts in partially edentulous simulating patient's oral conditions. Selection of material is well supported by **sorrentio et al**[35], **parameshwari et al**[31], for making impressions of multiunit angulated implants in partially edentulous patients.

Lee et al[4] suggested poly vinyl siloxane impression material as the material of choice when the implants were placed subgingivally. He preferred polyvinyl siloxane over polyether impression material for doing the same.

Vojdeni et al[6]., interpreted from his study comprising four implants in partial dentate maxillary acrylic models that polyvinyl siloxane seems to be better choice in non parallel conditions, followed by vinyl siloxane ether and polyether.

Impressions were poured and analyzed for discrepancies in reference to master model using coordinate measuring machine(CMM). Coordinate measuring machine was used, because the amount of discrepancy in reference to master model was measured three dimensionally, in contrast to other measuring devices such as strain gauges, vernier calipers and measuring microscopes, which performs it two dimensionally.

Among the samples tested, Groups Ia,Ib,Ic comprising three impression techniques for parallel implants were subjected to statistical analysis. Results revealed

that there is no statistical significant difference between 3 groups. As evident in the literature, the statistical evaluation can be justified that parallel implants doesn't pose humongous challenge to impression making since it doesn't cause distortion of impression material.

The threat arises, while making impression of non parallel implants, since it causes distortion of impression material, thereby causing dimensional inaccuracy. Study reveals that open tray splinted impression technique (GROUP IIb) showed better results than (GROUP IIa) closed tray impression technique though statistically not significant. Results of this study are in accordance with various authors.

In vivo study conducted by **gallucci et al[40]**, showed no significant difference between open tray and closed tray impression techniques in partially edentulous patients with less than 10º angulated implants. To analyse the outcome in partially edentulous patients with more angulated implants, 15º angulated implants were used in one study. Though there *is* no significant difference obtained statistically, open tray impression technique showed better values.

Even the open tray impression technique produced distorted impressions, when the angulation of the implants exceeded 25º to 30º. **Rutkunas et al[41]** reinforced this fact in his study, where open tray and closed tray impression techniques were employed to make impressions of 5º and 25º angulated implants.

In the present study, transfer copings were splinted with pattern resin to provide stability during open tray impression making. Splinted open tray impression technique provided superior results than the non splinted one. **Naconey et al[24]** supported this with his in vitro study that direct splinting technique was most accurate

transfer method for multiple abutments compared to direct non splinted and indirect techniques.

To overcome the disadvantages and limitations of conventional impression techniques, digital impression techniques were developed. Intra oral scanners made revolutions in the field of implant and prosthetic dentistry. It delineates the possibilities of error in various steps involved in the fabrication of prosthesis from impression making to cementation.

The accuracy of digital impression technique is reported less in the literature. The primary objective of the study is to provide added evidence to the existing literature regarding the accuracy of digital impression technique.

Papaspyridakos et al[37] claimed that the conventional open tray splinted implant level impressions and digital impressions produced similar results in terms of accuracy. This favours our study results in case of parallel implants, where as open tray splinting technique showed better results in case of non parallel implants though statistically insignificant.

In the present study, digital impressions of the master models were made by Medit i500 intra oral scanner and physical casts were made based on the mechanism of additive layering technique. The casts were then compared with the models obtained from conventional impression techniques (open and closed tray) for both parallel and non parallel implants. Similarly **Lin et al**[42] compared the accuracy of casts obtained from digital and conventional impression techniques in case of partially edentulous cases with two implants placed at varied divergent angles. The divergent angles of the implants tested were 15º, 30º and 45º. The accuracy of the casts

fabricated from conventional casts are superior compared to the milled casts obtained digitally. The present study results also report the same that the digital impression technique of non parallel implants with a tilt of upto 17º is less accurate than the open tray splinted impression technique and closed tray impression technique.

Sevcan et al[12] evaluated the accuracy of 3 impression techniques and 3 impression materials in parallel and angulated implants (10º or 20º) at the site of second premolar and second molar in master models simulating partially edentulous mandible. He concluded that the direct splinted technique was superior among the impression techniques and poly vinyl siloxane is the proven material of choice for impression. Though the models were analysed and the results were obtained digitally, the digital impression technique was not considered. The limitations of the a forementioned study was rectified in another study, where digital impression technique was compared against the open tray splinted and closed tray impression technique.

Henceforth the results of the present study was well supported by the literature showing that irrespective of any of the impression techniques (conventional or digital) parallel implants and implant placed with angulation till 15º the accuracy of impression among the techniques remain similar (no statistically significant difference). The real challenge occurs in more divergent implant angulations (>30º) where there is possibility of distortion of impression material to inaccurate transfer of three-dimensional implant position and angulation from the mouth to the master cast via impression thus compromising the fit of the prosthesis. Hence here comes the role of digital impression confronting the errors(3D discrepancies) discussed above in conventional impression techniques. But still the literature evidences for digital

impression remain insufficient and the available literature shows poor homogeneity of results which may be attributed to type of intraoral scanner in studies, inappropriate digital modeling process of original scanned data, CAD/CAM definitive cast milling, or during manual insertion of the implant analogs into the definitive casts. All these together demands for more studies to be conducted on digital impressions in future for more valuable evidences.

The present study can be further extended by including more number of implants with critical angulations, different implant-abutment configurations, different impression materials and different types of intra oral scanners using varying image acquisition technologies.

SUMMARY

Proper recording of the intro oral tissues is the prerequisite for an efficient prosthetic rehabilitation. Though numerous advancements and inventions of new materials and technologies widens the scope of treatment, efficient, wise selection and application of the same, results in successful outcome. The purpose of the present study is to assess and compare the accuracy of the conventional and digital impression techniques in parallel and non- parallel implants.

Closed and open tray impressions from PMMA master model poured using type IV dental stone and digital impression scanned using Medit i500 intra oral scanner and 3D models fabricated using photo active resin were fabricated and the positional accuracy of the casts were determined using Co-ordinate Measuring Machine.

The mean values of the closed tray, open tray , digital impression techniques and control for parallel implants were 14.523, 14.421, 14.276 and 14.264 respectively and those that for non- parallel implants are 14.327, 14,415, 14.272 and 15.575 respectively.

Though the results obtained showed no significant statistical differences among the accuracy of the impression techniques, the digital impression techniques shows relatively superior results with the mean value closely matching the control group in case of parallel implants and the open tray impression technique showing better results in case of non- parallel implants.

Hence within the limitations of the study, the accuracy of both the conventional and digital impression techniques are comparable, with the digital impression technique being an reliable alternative to conventional implant impression techniques.

CONCLUSION

1. For parallel implants, digital impression technique was found to be a little more precise followed by the open tray and then closed tray techniques respectively, even though there was no statistical significance in the test results.

2. For Non-parallel implants, open tray technique was found superior to closed tray and digital techniques respectively. But here also the results were not statistically significant.

3. Digital impressions perform almost equal to closed/open tray techniques in the case of parallel implants. All three techniques can be recommended.

4. Caution to be exercised when digital impressions are used for tilted implants when compared to the other two techniques.

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Adv. P. Asokan

ETHICAL CLEARANCE

The Study titled "**Comparative Evaluation of Accuracy of Conventional and Digital Impression Techniques for Implants Placed with and Without Angulation – An Invitro Study**" by **Dr. A Gnanavel**, Department of Prosthodontics, Rajas Dental College & Hospital, on scrutiny by the Rajas Dental College Ethics Committee (RDCEC) has been given Ethical Clearance to conduct the study.

Recommended for a period of 3 years

Date of Review: 12/12/2017

Dr. Shyam Mohan A. M.D.S., D.N.B.
MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
RAJAS DENTAL COLLEGE
KAVALKINARU, TIRUNELVELI DIST

Note:

- Inform RDCEC immediately in case of any adverse events and serious adverse outcomes.
- Inform RDCEC in case of any change of study procedure, site and investigator.
- The permission is only for the period mentioned above.
- Annual report has to be submitted to RDCEC.
- Members of the IEC have the right to monitor the trial with prior intimation.

Address for Correspondence:
Dr. SHYAM MOHAN A, Member Secretary, Rajas Detal College Ethics Committee, Rajas Dental College & Hospital, Kavalkinaru, Tirunelveli District, Tamil Nadu, India – 627105
Email: ethics@rajasdentalcollege.com

URKUND

Urkund Analysis Result

Analysed Document:	URKUND UPLOAD.docx (D61735688)
Submitted:	30/12/2019 17:29:00
Submitted By:	drgnanavelbds@gmail.com
Significance:	4 %

Sources included in the report:

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Inter implant distance for parallel implants obtained using different impression techniques (along X - axis)

Table 1: Mean value of three groups in Parallel Implants: Closed Tray, Open Tray and Digital Impression.

S.no	Closed tray group A	Open tray group B	Digital impression Group C
1	14.292	14.162	13.235
2	14.005	14.147	13.444
3	14.515	14.180	14.251
4	14.119	13.760	13.937
5	14.635	14.007	14.156
6	14.765	14.156	14.175
7	14.009	14.115	14.289
8	14.117	14.190	14.097
9	14.505	14.001	14.147
10	14.252	14.136	13.987
Mean	14.523	14.421	14.276

Inter implant distance for non parallel implants obtained using different impression techniques (along X - axis)

Table 2: Mean value of three groups in Non Parallel Implants: Closed Tray, Open Tray and Digital Impression.

S.no	Closed tray Group D	Open tray Group E	Digital Group F
1	14.501	14.826	14.227
2	14.200	14.974	14.931
3	14.822	14.305	13.868
4	14.858	14.674	13.937
5	14.219	14.297	14.261
6	14.259	14.259	14.259
7	14.555	14.197	14.768
8	14.815	14.237	14.229
9	14.197	14.211	14.297
10	14.807	14.229	13.987
Mean	14.327	14.415	14.272