USE OF OCCLUSAL PLANE ANALYZER IN DENTATE AND EDENTATE INDIVIDUALS TO MEASURE DEVIATION FROM IDEAL OCCLUSAL PLANE

A Dissertation Submitted to the

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In partial fulfillment of the requirement for the degree of

MASTER OF DENTAL SURGERY

(BRANCH I)
(PROSTHODONTICS AND CROWN & BRIDGE)

APRIL 2013

CERTIFICATE

This is to certify that this dessertation titled "**Use of occlusal plane analyzer in dentate and edentate individuals to measure deviation from ideal occlusal plane**" is a bonafied record of work done by **Dr Shah Darshan Jaydip** under my guidance during his postgraduate period 2010-2013. This dissertation is submitted to **Tamilnadu Dr. MGR Medical University**, **Chennai** in partial fulfillment, for the degree of **Master of Dental Surgery in Prosthodontics and Crown and Bridge (Branch-1).**

It has not been submitted (partial or full) for the award of any other degree or diploma.

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DECLARATION

I, Dr Shah Darshan Jaydip, do hearby declare that the dissertation **"Use of occlusal plane analyzer in dentate and edentate individuals to measure deviation from ideal occlusal plane"** was done in the Department of Prosthodontics, Tamilnadu Government Dental College & Hospital, Chennai- 600003. I have utilized the facilities provided in the Government Dental College for this study in partial fulfillment of the requirements for the degree of Master of Dental Surgery in Prosthodontics and Crown and Bridge (Branch -1) during the course period 2010-2013 under the conceptualization and guidance of my dissertation guide **Dr A. Meenakshi, M.D.S.**

I declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission from the Tamilnadu Government Dental College & Hospital, Chennai- 600003

I also declare, that no part of this work will be published either in the print or electronic media except with those who have been actively involved in this dissertation work, and I firmly affirm that the right to preserve or publish this work rests solely with the permission of the Principal, Tamilnadu Government Dental College & Hospital, Chennai- 600003, but with the vested right that I shall be cited as the author(s).

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PG Student

Witness

1.

2.

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Abstract

Introduction: For partially edentate patient, simplest and most accurate method of occlusal plane establishment is through the use of Broadrick occlusal plane analyzer. Because of fundamental racial differences in the craniofacial structures, the same dimensions advocated for other races should be evaluated for Indian population. With idea of replacing the missing structure in a manner they were present, the same method used for partially edentate and dentate patients, may have potential to be used for completely edentate patients.

Aim: To evaluate validity of Broadrick occlusal plane analyzer method for Indian dentate population and to apply this method for establishing the appropriate occlusal plane for complete denture patients

Materials and methods: 10 dentate and 10 edentate Indian subjects were selected as per predetermined criteria. For dentate individuals, maxillary and mandibular full arch impressions were made; casts were prepared and mounted in arcon semiadjustable articulator using facebow. Occlusal analysis was carried out with custom made occlusal plane analyzer and deviation of existing occlusal plane to that of the occlusal plane established by Broadrick occlusal plane analyzer was measured. For edentate patients, mandibular occlusal plane was established by considering anatomical landmarks; anteriorly corner of mouth, in the middle part lateral border of tongue and at the posterior end retromolar pad. The teeth were set according to the setting principles and occlusal analysis was done on artificial teeth of the trial denture. The differences between anatomically established occlusal plane and theoretically ideal occlusal plane were measured.

Results: For dentate group of the individuals the differences between existing occlusal plane and ideal occlusal plane were not significant statistically and clinically. For edentate subjects, the anatomically established occlusal plane had close resemblance to the ideal occlusal plane established by Broadrick occlusal plane analyzer method.

Conclusion: Within the limitation of the present study it can be concluded that:

(1) The Broadrick occlusal plane analyzer method of establishing occlusal plane is valid for the Indian population
(2) The Broadrick occlusal plane analyzer may have potential to be used in fabrication of complete denture for establishing posterior occlusal plane.

The future study should include large sample size with anatomical variations and should consider clinical applicability and related aspects for the proposed method.

INTRODUCTION

The configuration of the occlusal plane is one example of nature's beautiful and intricate designs. The dynamics of function play out so precisely with the arrangement of teeth. All components of this complex design are functionally interrelated. Any alteration in one aspect of this design can have deleterious effects in another

A further description is voiced by Dr. Peter Dawson who says, "The plane of occlusion refers to an imaginary surface that theoretically touches the incisal edges of the incisors and the tips of the occluding surfaces of the posterior teeth."[1]

When we relate to a plane we initially think of a flat surface. However, this is not the case with the occlusal plane.

According to GPT occlusal plane has been defined as[2]

1: The average plane established by the incisal and occlusal surfaces of the teeth. Generally, it is not a plane but represents the planar mean of the curvature of these surfaces

2: The surface of wax occlusion rims contoured to guide in the arrangement of denture teeth

3: A flat metallic plate used in arranging denture teeth

If we analyze the definition of occlusal plane, it describes occlusal plane in dentulous and edentulous, both conditions. The first part of the definition is related to

dentulous cases while the remaining two parts describe occlusal plane for edentulous cases.

In many partially edentulous conditions requiring fixed prosthesis, there may be pathological alteration in occlusal plane resulting from rotation, tipping, and extrusion of teeth. The rehabilitation of such cases requires correction of the occlusal plane.

The 3 most commonly used methods for establishing an acceptable plane of occlusion are direct analysis on natural teeth through selective grinding, indirect analysis of facebow-mounted casts with properly set condylar paths, and indirect analysis using the Pankey- Mann-Schuyler (PMS) method with the Broderick occlusal plane analyzer (BOPA).[3]

It has been determined that restoration of all or most of the posterior teeth is necessary, the PMS technique using Broadrick occlusal plane analyzer provides a simple and practical method to assist in determining the preliminary occlusal plane on diagnostic casts.

The Broadrick occlusal plane analyzer, also known as *Broadrick flag*, has now been adapted to only a few articulator systems, such as the Denar Anamark Fossae (Teledyne Waterpik, Ft Collins, Colo) and all models of Hanau articulators (Teledyne Waterpik).[4, 5] For those manufacturers of semiadjustable articulators who do not offer such occlusal plane analyzers for use with their instruments, a custom made clear acrylic resin Broadrick occlusal plane analyzer may be fabricated.[6]

While the Broadrick flag has been commercially available for over 40 years, the review of literature revealed only few efforts to support the contention that the curve it produces exists in the natural dentition.

The complete denture prosthestics is the field of dentistry which places the maximum number of important factors in the control of the clinician. here the operator is concerned with the form and relative position of the ridges; the positioning of the artificial teeth in relation to the ridges; arrangement of anterior teeth for esthetics; determination of incisal guidance angle; condylar function and the combined influence of the incisal guidance angle and condylar function on the orientation of the plane of occlusion.

The success in rehabilitating function, esthetic and phonetics with complete denture prosthetics is interplay between all these factors. For example, the form and size of the artificial teeth should be in accordance with the incisal guidance, the horizontal and lateral condylar guidance, the compensatory curves and the orientation of plane of occlusion.

The correct orientation of the occlusal plane plays vital role in esthetically and functionally successful complete denture prosthesis. The review of literature reveals important aspects of orientation of occlusal plane. Various authors have proposed theories about the orientation of occlusal plane and depending on that they have advocated different methods for locating the occlusal plane. There appears to be lack of agreement on how it should be orientated for individual patients.

The commonly used method is based on anatomical landmarks which advices the positioning of occlusal plane parallel to the plane between the corner of mouth and the junction of middle and upper third of the retromolar pad.

However, all the authors agree that ideal location for the occlusal plane is in the same position as it was when the natural teeth were present. Theoretically, plane established by Broadrick occlusal plane analyzer method has been considered as ideal occlusal plane for dentulous and partially edentulous individuals.

In case of edentulous individual, after anterior teeth were set, which is guided by phonetics and esthetics; tip of the canine and condylar element of the articulator can be taken as anterior and posterior survey points, respectively, for Broadrick occlusal plane analyzer method. The plane established by Broadrick occlusal plane analyzer method can be important guide for establishing plane in complete denture cases if anatomically established plane and plane established by Broadrick occlusal plane analyzer method coincide to each other.

The present study was undertaken

1. To evaluate the relationship of occlusal plane established by Broadrick occlusal plane analyzer method to existing occlusal plane of dentate patient
2. To analyze relation between anatomically established occlusal plane and occlusal plane established by Broadrick occlusal plane analyzer method for edentate patients.

AIMS AND OBJECTIVES

Aim of the study:

To evaluate validity of broadrick occlusal plane analyzer method for Indian dentate population and to apply this method for determining the appropriate occlusal plane for complete denture patients

Objectives of the study:

To find out the deviation of existing occlusal plane in Indian dentate individuals with that of the occlusal plane established by Broadrick occlusal plane analyzer method.

To measure the difference between anatomically established occlusal plane of edentate patient and the same established by Broadrick occlusal plane analyzer method.

REVIEW OF LITERATURE

For functional and esthetic rehabilitation of partially and completely edentulous patients, the occlusal plane is important parameter. The occlusal plane functions to harmonize morphology and function of stomatognathic system. The occlusal plane forms the fundamental of successful clinical management of edentulism, both partial and total.

Over a period of time, many authors have proposed various concepts and methods for occlusal plane establishment in both completely and partially edentate patients. The literature shows ongoing debate about the ideal method for occlusal plane establishment.

The review of literature focuses on various aspects as they are related to occlusal plane for partially and completely edentulous patients.

The review of the literature is divided into three parts:

1. Concepts of occlusal plane in dentate individuals
2. Occlusal plane analyzer and related literature
3. Geometry of occlusal plane in edentate patients and methods to establish the same.

Concepts of occlusal plane in dentate individuals

Occlusal reconstruction of the natural dentition is complex treatment modality. The concept of occlusion opted for rehabilitation should preserve the health of stomatognathic system. In case of missing multiple teeth establishment of occlusal plane for optimum esthetic and function is difficult. The condition may be further complicated by rotation, tipping and supraeruption of the remaining teeth. The studies

have proposed methods to establish the plane depending on anatomical landmarks, cephalometric images or anthropologic observation.

Over a period of last one and a half centuries, various authors have described geometry of occlusal plane on a basis of anatomical landmarks. The anterio-posterior curve was originally described by **Ferdinand Graf Spee**[7], known as curve of Spee. According to his classical explanation, in normal natural dentition, there exits an anteroposterior curve which passes through the cusp tip of the mandibular molar mandibular canine and the buccal cusp tips of the mandibular premolars and molars, and further extends in a posterior direction to pass through the most anterior point of the mandibular condyle. This curve is present in sagittal plane. It is best appreciated from a lateral aspect. According to Spee, the center of the curve lies along "a horizontal line through the middle of the orbits behind the crista lachryma posterior,"[8] . As per Spee's classical explanation, the radius of the curve was observed as 2.5-inch. Spee noted that the center of the curvature can be located "by reconstruction and measurement with the compass."

In 1920, **George Monson**[9] proposed 3-dimensional configuration of the occlusal curve in a form of sphere. He formulated a 3-dimensional occlusal philosophy by combining the concepts of Bonwill's 4-inch triangle and bilateral balanced occlusion, Von Spee's compensating curve (anterior-posterior and buccal-lingual curvature), and the observances of Blackwill and Christensen on condylar movement[10]. Basically, Monson combined anteroposterior and mediolateral curves to describe geometry of occlusal plane. He proposed the sphere that passed through the incisal edges and occlusal surfaces of the mandibular teeth. The surface of the sphere

is concave for mandibular teeth and convex for maxillary teeth. Monson advocated radius of 4-inch for the sphere in place of radius of 2.5 advocated by Spee. Monson's concept has been accepted widely in contemporary practice. Most investigators and clinicians follow the concept given by Monsoon for occlusal rehabilitation.

For description of occlusal plane geometry, Law of tangent has also been advocated. **Orthelib**[11], in 1997, conducted study on cephalometric images to establish fundamentals of occlusal plane geometry. The investigation involved 470 subjects. He concluded the mandibular incisors followed the tangent law. The posterior mandibular teeth followed a progressive differential angle with the direction of the tangent. It was also evident from the study results that significant variations in the curve were related to degree of overbite and skeletal relation

The curve of Monson is usually evaluated in one of its two-dimensional projects, namely in the frontal plane at the level of the molars (the curve of Wilson), and in a sagittal plane parallel to the alveolar process (the curve of Spee).

Authors have listed several hypotheses proposed to explain the functional significance of this morphological arrangement which are as follow:

1. The biomechanical consideration which advocates that because of incorporation of curve of Monson in dentition, the dentition will have better resistance against forces of occlusion and chewing, which will increase the stability of the dental arches[12]
2. The functional consideration attempts to describe the arrangement of teeth based on increase in chewing efficiency in molar region[13]

3. Dynamic considerations are related to protrusive movements correlating the curve of Spee, the angle of the eminentia, molar cusp height, incisor overbite and the posterior contacts.

In 2002, **Mauro Farella *et al***[14], investigated the relationship between the curve of Spee and skeletal facial morphology with multiple regression analysis. The cephalometric analysis investigated the sagittal and vertical craniofacial dimensions and the position of the mandibular condyle with respect to the occlusal plane. Dental casts and lateral cephalograms were obtained from 59 orthodontic patients. The amount of concavity of the curve of Spee was calculated from lateral digital photographs of the teeth. The variables considered in a multiple regression analysis were able to explain 34% of the total variance of the curve of Spee.

The study concluded that the amount of the curvature for curve of Spee was significantly related to

1. The horizontal position of the condyle in relation to the dentition,
2. The position of the mandible with respect to the anterior cranial base in sagittal aspect, and
3. The ratio between the posterior and anterior facial height.

The study further indicated that

1. The curve of Spee does not have any significant relation with any of the other cephalometric variables.
2. The age and gender of the subjects investigated did not have any influence on the curve of spee.

V. F. Ferrario and coworkers[15], in 1997, analyzed three-dimensional curvature of the mandibular dental arch. In this study, three dimensional positions of cusp tips of all but the third molars were obtained with a three-dimensional digitizer. With this data spherical model of the occlusal plane was obtained. From the best interpolating sphere the radii of the left and right curves of Spee (sagittal plane) and of the canine and molar curves of Wilson (frontal plane) were computed. They concluded with:

1. The occlusal curvature of the mandibular arch was not significantly influenced by gender, even though all the computed variables were larger in men than women.
2. The radii of the overall sphere, right and left curves of Spee, and curve of Wilson in the molar area were about 105 mm in men, and about 100 mm in women.
3. A relatively large intra sample variability in arch curvature was found. The mean sphere radius in men was very close to the classical value of 4 inch which confirms Monson's observation. Because of large intra sample variability it was not possible to conclude definitively about influence of gender on three-dimensional characteristics of occlusal curvature.

In 2004 **Hui Xu *et al***[16] evaluated the curve of Spee in the maxilla and mandible of human permanent dentition. The purpose of this study was to investigate the differences in the curve of Spee between the maxillary and mandibular arches and the effects of gender on the curve of Spee. In the study total 50 Japanese adults were examined. For all patients standardized digital picture of the right side of maxillary and mandibular dental casts were made with a digital camera with predetermined

settings. On digitalized images cusp tips of the molars, premolars, and canines of the maxilla and mandible were identified. The computer software was used to measure the radius and depth of the curve of Spee on dental cast.

The results indicated

1. In subjects observed the radii of the curves of Spee in the maxillary arch were significantly larger than those in the mandibular arch
2. The depths of curve were approximately 1.6 mm in the maxillary arch and 1.9 mm in the mandibular arch.
3. The depth of the curve of Spee in the mandibular arch was significantly deeper than that in the maxillary arch.

The authors concluded that

1. The gender of the subjects investigated did not have influence on curve of spee.
2. The shape of the curve of Spee in the maxillary arch was significantly flatter than that in the mandibular arch

Fu and coworkers[17], 2007, analyzed geometry of occlusal plane related to Hamular notch-Incisive papilla plane in 100 Taiwanese young adults. In their evaluation all the predetermined points were marked precisely and three dimensional measurements were made. Depending on these points four geometrically different occlusal planes were defined. The angular relationship between the four occlusal planes and the Hamular notch-Incisive papilla plane were investigated. The data was collected by measuring vertical distances between the cusp tips and incisal edges of maxillary teeth to the Hamular notch-Incisive papilla plane. The results indicated that

the Hamular notch-Incisive papilla plane occlusal plane tends to be parallel to the occlusal plane in subjects, which may be used as a clinical practice guideline.

Jayachandran *et al*[18] , 2008, studied orientation of occlusal plane for total of 90 dentate and edentate Indian individuals (60 dentate, 30 edentulous) in relation to hamular notch/incisive papilla plane (HIP). The study indicated that the mean differences from the right canine were: 0.055 cm at the left canine, 0.05 cm at the right molar, and 0.065 cm at the left molar in dentate subjects and 0.001 cm between the incisive papilla and hamular notch in edentulous subjects. The paired *t*-test showed no statistically significant difference. Hence it was concluded that Hamular notch-Incisive papilla plane is parallel to the occlusal plane in subjects evaluated.

Occlusal plane analyzer and related literature

The 3 most commonly used methods for establishing an acceptable plane of occlusion are direct analysis on natural teeth through selective grinding, indirect analysis of facebow-mounted casts with properly set condylar paths, and indirect analysis using the Pankey- Mann-Schuyler (PMS) method with the Broderick occlusal plane analyzer (BOPA).

In concept for full mouth rehabilitation **Pankey and Mann**[19] described the method for establishing the occlusal plane by using Pankey-Mann instrument in 1960. The design of the device followed the 4-inch radius for establishing the mandibular posterior occlusal plane. The use of instrument helped in establishing occlusal plane for successful rehabilitation of the patient. The design and application of the instrument was complex. The design of the instrument was simplified by Broadrick.

In 1963, **Dr Lawson Broadrick**[20] developed an instrument to provide a guide to the most suitable position and orientation of the posterior occlusal scheme where the natural Curve of Spee has been deranged. Dr Broadrick worked on Spee's comment: "The center of the curvature of curve of spee can be located by reconstruction and measurement with the compass." The instrument designed by him is known as Broadrick occlusal plane analyzer, more commonly as Broadrick's flag. This instrument includes a laminated piece of cardboard that is attached to the superior aspect of the upper member of a semi-adjustable articulator. Its purpose is to permit reconstruction of the Curve of Spee in harmony with anterior and condylar guidance. This instrument has been adapted to the some articulator systems by the manufacturers.

In 1972, **McLaughlin**[21], described Adaptation of an occlusal plane analyzer to a semiadjustable articulator, he described the procedure to adapt, broadrick occlusal plane analyzer, model 142-1, Hanau engineering Co,. to the Whipmix articulator systems.

The Denar articulator systems[22] have adopted simplified occlusal palne analyzer which is known as Simplified occlusal plane analyzer. The Simplified occlusal plane analyzer is still more simplified form of occlusal plane analyzer. The Simplified occlusal plane analyzer system automatically establishes the position of the centre of curve in correct relation to the condyle. Therefore Simplified occlusal plane analyzer system requires single survey point when compared to two points needed for Broadrick occlusal plane analyzer.

Wynne[23], in 2005, developed occlusal plane analyzer system for Sam 3 articulator system. The system was basically similar to broadrick occlusal plane analyzer for other articulator systems. The wynne occlusal plane analyzer added to the advantages of Sam series of articulators.

Lynch and McConnel[24] described the use of teeth for both the anterior and posterior survey points for determination of the occlusal curve. In their study, the mandibular canine was selected as the 'Anterior Survey Point' from which an arc of 4 inches was drawn using the compass on the Broadrick flag. The distal incline of the disto-buccal cusp of the most distal molar was selected as the 'Posterior Survey Point' (PSP). The inrsecting point was used as center of the circle which forms occlusal part. The article described the importance of curve of Spee in prosthodontic dentistry and successful prosthodontic management of the patient.

Toothaker and Angela[25] described a simple modification for adaptation of an occlusal plane analyzer to semiadjustable articulator. The articulator selected was model 2240, Whimix Corp. On upper member of the articulator the occlusal plane analyzer (No. D122, Teledyne WaterPik, Fort Collins, Colo) was adapted by using commonly available dental laboratory tools. Before this adaptation, the practitioner was limited to the use of the Hanau semiadjustable or Teledyne WaterPik semiadjustable or fully adjustable instrumentation for such direct occlusal plane analysis. The main advantage of the procedure was the ability of the practitioner to easily use semiadjustable articulator with Teledyne WaterPik occlusal plane analyzer as accessory for prosthodontic rehabilitation.

Bedia and coworkers[26] described method for determination of occlusal plane by using custom-made occlusal plane analyzer. The flag part of the occlusal plane analyzer was fabricated using a 2-mm-thick clear acrylic resin sheet. It was fitted into the slot of the same dimensions in clear acrylic resin base which was attached to the upper member of the articulator. A sheet of blank paper was attached to both sides of the flag to receive the markings. The surveying was done and required correction in the occlusal plane was done to rehabilitate the patient with fixed restorations. The articulator used was model 8800 Whipmix Corporation.

Craddock *et al*[27] evaluated reliability of broadrick ideal occlusal palne to the existing occlusal plane in dentate patients. The study covered 100 subjects with full complement of teeth present. The study also included the parameter for determining intra-examiner reliability. Out of 100 patients examined, 55 individuals had plane of occlusion which coincides with the plane established by broadrick occlusal plane analyzer. The results demonstrated little deviation from broadrick ideal occlusal plane for the subjects studied. Good intra-examiner reliability was also noticed by the author.

In 2006, **Craddock and coworkers**[28] studied deviation of occlusal plane from broadrick occlusal curve following posterior teeth loss. The study included 180 individuals (90 subjects and 90 controls). The subjects selected were missing posterior teeth for 5 years or more. It was evident from the study that when posterior tooth has remained unopposed for long duration, the positional changes in tooth would have caused deviation from the Broadrick curve. The Broadrick occlusal plane analyzer can provide accurate reproduction of the occlusal curve for such cases.

Supriya Manvi *et al*[29] investigated applicability of the custom made occlusal plane analyzer for occlusal plane determination. The purpose of the study was to determine the appropriate occlusal curve for individual patients and to compare the deviation of the clinical occlusal curve with the ideal ones. The study involved total of 20 subjects (10 completely dentate individuals as control group and 10 partially dentate subjects). In this study the deviation of the occlusal plane was recorded on the articulated cast and data was collected on original object itself, unlike other studies where readings were made on photographs or scanned images. The results indicated marked deviation from ideal occlusal plane for partially edentulous subjects as compared to completely dentate controls. The study indicated that the Broadrick occlusal plane has close relation to the existing occlusal plane of dentate patients. It was evident from the study that the proper utilization of the broadrick flag on a semi-adjustable articulator will allow for a correct determination of the occlusal plane.

In 2012, **Jagadeesh KN *et al*** [30]verified reliability of Broadrick flag in Indian population. The study was done to verify radii of curvature of Spee by Lynch and McConnell. The study included subjects with skeletal class I, II and III jaw relations. The results indicated the validity of the broadrick flag method for Indian population and advocated use of 4-inch radii for Class I, 3.75-inchh radii for Class II and 5-inch radii for Class III.

For diagnosis and correction of the occlusal plane of remaining natural teeth in dental implant treatment, **Misch** [31] also had advocated use of occlusal plane analyzer

.

The literature documented use of occlusal plane analyzer for WhipMix, Hanau, Denar and SAM 3 articulator systems. The literature indicated possibility of adapting the manufacturer supplied occlusal plane analyzer to the specific articulator system. Moreover it was also possible to fabricate the custom made occlusal plane analyzer for the articulator. But during such procedure, certain basic principles should be followed. The validity of the occlusal plane analyzer has been documented by various authors. The occlusal plane analyzer is widely accepted tool for establishing occlusal plane which has applications in the full mouth rehabilitation, removable complete denture replacing multiple teeth and single complete denture.

Geometry of occlusal plane in edentate patients:

In complete denture construction geometry of occlusion plays vital role for esthetic, function and stability of the prosthesis. Over a period of years many authors have presented their views and methods for occlusal plane establishment. The proposed methods for establishing occlusal plane include methods depending on intraoral anatomical landmarks, vestibular impression technique, and cephalometric image. Various authors have documented effect of skeletal pattern on occlusal plane orientation. Moreover longitudinal cephalometric studies have documented long term changes in craniofacial complex and occlusal plane. All authors have observed the occlusal plane in dentate individuals first. Depending on which they have conceptualize the technique for orientating occlusal plane for edentate patients. Some of the methods for orientation of the occlusal plane considers following concepts:

1. Incisive papilla and hamular notches are related to the occlusal plane
2. Corner of mouth, lateral border of tongue and retromolar pad place the occlusal plane similar to the its natural counterpart

3. Opening of parotid gland duct dictates the level of maxillary occlusal plane.
4. In vestibular impression technique, deep horizontal groove cut by the buccinators muscle dictates the orientation of occlusal plane.
5. Occlusal plane parallel to the camper's plane.

In 1953, **Sloane and Cook**[32], studied the relation between fixed cranial landmarks and plane of occlusion. For study purpose relation between two planes were considered. the two planes were plane of occlusion and Cook's plane which passes through anterior nasal spine and hamular notches. The study results indicated:

1. The Cook's plane forms angle with the plane of occlusion which falls within predictable limits.
2. There is a relation between angle formed by Cook's plane and plane of occlusion, and distance between anterior nasal spine and hamular notch.
3. There was a certain bilateral asymmetry in skulls and casts studied but its effect on basic relation was not significant
4. Though the distances from the anterior nasal spine and the hamular notches to the plane of occlusion varied, the difference between the two measurement approaches the constant, enough to permit the practical use of the average value.
5. As far as esthetic is concern, the anterior aspect of the plane of occlusion should be kept parallel to the pupils of the eyes.

The study also indicated that, it is important to select the reference points which would not be affected by the degenerative process and that should readily be identified on the edentulous maxillary cast. Because ANS is difficult to locate on the cast, incisive papilla can be used as reference point.

Hall[33], in 1958 had an idea that each patient's occclusal plane is consistent with his oral physiology and esthetic need. To establish any plane in space, 3 points must be established. In case of denture occlusal plane out of these three points, one is located in the anterior region and one in each posterior segment. Anteriorly the point is determined by the length of the incisal edge of the upper occlusion rim above or below the upper lip and lip is properly supported. The two posterior points are established depending on the height of distal half of the retromolar pad on each side. The occlusal plane is parallel to the ridge planes.

Boucher[34], 1963 had an opinion that the occlusal plane should be established in a way so that it will resemble the plane of occlusion of natural teeth when they were present. According to his principle the anterior teeth should be positioned correctly for esthetic requirements and posterior end of occlusal plane should be located approximately at the level of distal part of the retromolar pad.

In roentgenographic study, **Ismail and Bowman**[35] , in 1968, compared the position of occlusal plane of the artificial teeth with that of the natural teeth which were present at that time, before the remaining teeth extracted. The occlusal plane for trial dentures were first established parallel to the ala-tragus line and then was modified in such a way that the occlusal surface of the second molars were placed at the level of the middle third of retromolar pad. In posterior region, this position of the occlusal plane was found to be at lower level than the plane of natural teeth. These observations indicated that the occlusal plane should be established so that the second molars should be located at the level of upper third of the retromolar pad.

L'Estrange and Vig[36] , in 1975, studied relation between location of occlusal plane and maxillomandibular space in dentulous and edentulous individuals. The results indicated close relation angular relation between occlusal and maxillary planes in both groups. As far as dentulous subjects were concerned, there was a significant relation between angulation of the occlusal plane to the maxillary plane and maxillomandibular space. When maxillomandibular space was long-and-low type, the occlusal plane was parallel to the maxillary plane. While in case of short-and-high maxillomandibular space, the occlusal plane was steeply angulated to the maxillary plane. The study concluded that the extremes of maxillomandibular space available will cause deviation of occlusal plane away from a mean angulation of maxillary plane.

In 1983, **Douglas and coworkers**[37] presented the results of their chephalomatric study conducted on edentulous complete denture wearers over a period of 20 years. The study was designed to investigate the changes in the craniofacial complex of the subjects included in the study. The following observations were made in the study:

1. Over a period of time, the mandible rotated counterclockwise. The result of this rotaiton was loss of vertical dimension and an increase in relative mandibular prognathism
2. As compared to maxillary bony edentulous ridge, the mandibular one was significantly reduced in study duration.
3. Because of changes in craniofacial complex the dentures exhibited counterclockwise rotation and mild amount of anterior shift

4. As far as gender was concerned there were no significant differences. Moreover the patient group using standard dentures had similar changes like group of patients using complex dentures.

Tuncay and coworkers[38], in 1984, documented the results for cephalometric study over a period of 10 years. The aim of the research work was to study the changes in craniofacial complex, residual ridge resorption and position of the dentures as related to cephalometric landmarks. The study attempted to establish the relation between changes in craniofacial complex and factors such as; age, sex, skeletal pattern, duration of edentulousness, technique for denture fabrication and wearing of denture during night time.

The results of the study were as follow:

1. Both, maxilla and mandible showed counterclockwise rotation in sagittal plane.
2. The complete dentures were appeared to be rotated counterclockwise with associated forward movement.
3. The positional changes in the complete dentures were more related to the soft tissue component as compared to residual ridge resorption.
4. The observed changes were not associated with the denture technique used.
5. The porcelain teeth of the dentures were not attrited significantly over a study period of 10 years.
6. Factors such as; age, sex and wearing of denture during night time; did not have influence on the changes observed.
7. The skeletal pattern had an influence on degree of prognathism over a period of time

8. The amount of mandibular ridge resorption was associated with the duration of edentulism.

In 1985, **Van Niekerk**[39] conducted a cephalometric study where complete dentures were fabricated with criteria other than the ala-tragus line used to establish the occlusal plane. The patients included in the study were satisfied with esthetic, function and comfort of the prosthesis. The lead foil was adapted to the right mandibular posterior teeth to indicate the occlusion plane. Another lead foil was positioned over a face from lower border of ala to the tragus. The cephalogram was obtained to study the relation between two markers. The results showed significant parallelism between the two markers. The study concluded the ala-tragus line is closely associated to the occlusal plane and it can be used as landmark to establish the occlusal plane for complete denture patients.

Monteith[40] in 1985 studied the correlation between the PoNANS (Porion-Nasion-Anterior Nasal Spine) angle and occlusal angle formed by intersection of the occlusal and Frankfort planes. The result of the research showed significant correlation between the angles studied. An increase in the orion-Nasion-Anterior Nasal Spine angle has a tendency to flatten the orientation of the occlusal plane; while acute orion-Nasion-Anterior Nasal Spine angle results in steeper occlusal plane. The investigation also indicated that based upon the known value of either angle, the unknown value of the remaining angle can be established with high predictability.

In continued investigation, **Monteith**[41] in 1986 studied the accuracy of the earpiece facebow in transferring the Frankfort horizontal plane to the articulator and

the reliability of orion-Nasion-Anterior Nasal Spine angle produced occlusal plane orientation in establishing natural looking dental composition. The difference between the radiographic and predicted occlusal plane angles was such that the final angle obtained was in no case greater than that originally intended. The flattening effect observed can be attributed to idiosyncrasy manifesting as a tendency to locate the orbitale reference on the patient's face at a point slightly higher than its corresponding bony level. Alternatively, the weight of the face-bow might have been sufficient to cause the ear-rods to sag slightly, thus lowering the posterior reference point.

In 1987, **Karkazis and Polyzois**[42] studied relation of artificial and natural dentition occlusal plane to the Camper's plane in cephalometric images of 18 dentulous and 56 complete denture wearers. The results of the study can be summarized as follow:

1. The natural dentition occlusal plane was not parallel to the Camper's plane. The deviation ranged from -5° to +9°. The average deviation was noticed as 2.88°
2. The artificial occlusal plane was not parallel to the Camper's plane, as noted at the prosthesis insertion appointment. The deviation varied from -7° to +13° with an average of 3.25°.
3. The anteroposterior inclination of the artificial dentition occlusal plane was almost similar to that of the natural dentition.

Karkazis and Pylozois[43] ,in 1991, incontinued research on geometry of occlusal plane. In 1991 they conducted cephalometric study to check the hypothesis

that the angulation of the occlusal plane is generally related to the skeletal base of the maxillae.

The study concluded:

1. As per regression formula used in investigation, there was no evidence to accept the reliability of any of the three studied parameters (Cook's plane, ANS-PNS and PoNANS) to establish the occlusal plane with high accuracy.
2. The Hamular notch-Incisive papilla plane tends to parallel the occlusal plane which can provide guideline for occlusal plane determination. But the reliability of the method should be verified by further clinical application.
3. The formula given by Monteith can provide the occlusal plane which is closely related to the clinically determined one.

Celebice[44], in 1995 investigated the reliability of the intraoral method of occlusal plane determination which orients the occlusal plane to terminate at the upper level of the retromolar pad. Total of 64 individuals (30 completely dentate controls and 34 complete denture wearers subjects) were included in the study. The stone casts from each patient were obtained and mounted in SAM 2 articulator by quick mount face-bow transfer. For both the groups, the data was collected by measuring angle between the occlusal plane and the articulator horizontal plane. For dentate group of individuals the angle was 9.42° +/- 4.1° while the angle of 8.53° +/- 2.80° was noted for edentate group. Statistically there was no significant difference between the values obtained from both groups. The results indicated that the intraoral method for occlusal plane determination for edentate patient can be used with high predictability which will be similar to the occlusal plane of natural dentition.

Nissan[45] in 2003 investigated the relationship between commonly used anatomical structures to determine the occlusal plane and the facial skeletal shape of complete denture wearers using cephalometric analysis. During investigation no correlation was found between the anatomical structures that could be used to establish the occlusal plane in edentate patients with high predictability. The current status of the cephalometric analysis can only be limited as a rough guide to occlusal plane location. The wide variation in anatomical structures between individuals can be attributed for limited applicability of the cephalometric analysis. For occlusal plane determination, intra-oral structures must be considered.

Shigli[46], in 2005, evaluated applicability of certain intraoral landmarks to determine the plane of occlusion. The location of occlusal plane was studied in relation to retromolar pad, parotid papilla and buccinators grooves. By utilizing vestibular impression technique it was possible to establish the occlusal plane with respect to intraoral anatomical landmarks. The study supported a close correlation among occlusal plane, buccinators groove and parotid papilla.

MATERIALS AND METHODS

This in-vivo study was carried out to compare the natural occlusal plane in dentate individuals and anatomically established occlusal plane in edentate patients to the theoretically ideal broadrick occlusal plane. The study was done on the articulated casts of the individual and differences between the two planes were measured. This study was performed from January 2012 to December 2012 in the Department of Prosthodontics, Tamilnadu Government College and Hospital, Chennai.

ETHICAL COMMITTEE APPROVAL

The study was done after obtaining approval from the Institutional Ethical Committee.

The following materials and equipments were used during the study

FOR DENTATE INDIVIDUALS:

For examinaiton:

Mouth mirror

Straight explorer

Kidney tray

Gloves

Mask

For impression making:

Rubber bowl

Alginate mixing spatula

Measuring scoop for alginate

Measuring jar for water

Perforated stock metal tray

Irreversible hydrocolloid impression material

Type III dental stone

For facebow transfer and articulation:

Ear piece type Face bow (Bio-art professional facebow)

Semi-adjustable, arcon articulator (Bio-art A7 Plus articulator)

Dental plaster

Bite registration medium

For occlusal analysis:

Customised occlusal plane analyzer

Compass

Colored Pencil

Scale

Digital vernier calliper

FOR EDENTATE PATIENTS:

For examination:

Mouth mirror

Straight explorer

Kidney tray

Gloves

Mask

For primary impression making:

Impression compound

Hot water bath

Maxillary and mandibular stock metal tray

Bard parker blade no 15 and handle

Chip blower

Rubber bowl

Autopolymerising resin

For secondary impression making:

Custom made self cure acrylic tray

Tracing compound

Metallic oxide impression paste

Mixing spatula

Oil impervious paper

For making record base:

Autopolymerising acrylic resin

Wax sheet

Hot plate

Was spatula and wax knife

For recording jaw relation and facebow transfer:

Thread

Fox plane

Scale

Indelible marker

Ear piece type slidematic Face bow (Bio-art professional facebow)

Semi-adjustable, arcon articulator (Bio-art A7 Plus articulator)

Dental plaster

Semianatomic teeth set

For occlusal analysis:

Customised occlusal plane analyzer

Compass

Colored Pencil

Scale

Digital vernier calliper

Materials used in the study:

S.No	Name (Commercial Name)	Form of The Material	Manufacturer Details
1	Aslate impression compound	Impression compound	Aslate, India
2	Jabbar trays	Stock tray	Jabbar & Co., India
3	White gold	Type II dental plaster	Asian chemicals, India
4	DPI Pinnacle tracing sticks	Green stick compound	DPI, The Bombay Burmah Trading Co., India
6	Kalstone	Type III dental stone	Kalabhai & Co., Mumbai , India
7	Rolex modeling wax	Wax sheet	Ashoo & Sons, India
8	CAD Bite	Bite registration medium	Ivoclar, vivadent, USA
9	DPI Self Cure	Autopolymerising acrylic resin	DPI, The Bombay Burmah Trading Co., India
10	DPI Impression paste	Zinc-oxide impression paste	DPI, The Bombay Burmah Trading Co., India
11	Vignette	Irreversible hydrocolloid impression material	Dentsply, india
12	acryrock	Semianatomic teeth set	Ruthenium group

METHODOLOGY:

Source of data

Subject selection

Fabrication of custom occlusal plane analyzer

Method of collection of data for dentulous subjects

Making primary and secondary impressions and casts for edentate patients

Making record bases and wax occlusal rims

Establishing occlusal plane by anatomical method

Facebow transfer and mounting of maxillary cast on articulator

Making of interocclusal record and mounting of mandibular cast on the articulator

Teeth setting and wax trial

Occlusal plane analysis

Source of data

Patients reporting to the Department of Prosthodontics, Tamilnadu Government Dental College and Hospital, Chennai

Subject selection

The study was done between two groups viz.

Group 1: consisting of 10 dentate individuals and

Group 2: consisting of 10 completely edentate patients

Selection criteria

	Group 1	Group 2
No. of Sample	10	10
Age group	20-25	60-75
Gender	Male and Female	Male and Female

Inclusion criteria:

For dentate subjects:

All teeth from second molar to second molar should be present in both the arches

Bilateral Class 1 molar and canine relation

Normal horizontal and vertical overlap

For edentate subjects:

Class 1 ridge relation observed at the time of diagnostic mounting

Good neuromuscular control

Healthy denture bearing mucosa

Mild to moderate residual ridge resorption

Exclusion criteria:

For dentate patient:

Class 2 or class 3 canine and molar relaiton

Any missing teeth among second molar to second molar in either arch

Rotation, tipping, supra eruption, worn dentition

Parafunctional habits

TMJ disorder

Present or past orthodontic treatment

Extensive restorations and attrition of the teeth

Periodontal pathology

For edentate patient:

Maxillary or mandibular prognathism observed at the time of diagnostic mounting

Patient with neuromuscular and TMJ disorders

Severe residual ridge resoption

Patient with psychological disorders

Preparation of customized occlusal plane analyzer:

For bio-art articulator system, occlusal plane analyzer is not available by the manufacturer. For present study, customized occlusal plane analyzer was made for Bio-art A7 plus articulator. For preparation of customized occlusal analyzer the method advocated by **Sumit Bedia et al** [26]was followed with some modification.

The supporting rod of the articulator was duplicated in aluminium. The piece of stainless steel was prepared in 10cm in height and 11 cm in width. The piece was encircled around the duplicated rod and was fixed to the rod with screws. Rigidity of the joint was assessed. The original supporting rod was removed and the duplicated rod along with piece of metal was placed in that position. The junction of the rod and piece of metal was adjusted so that the piece of metal falls exactly in the middle of the upper member. Graph paper was pasted on the piece of metal on both the sides. This custom made occlusal plane analyzer was used for the study purpose.

Method of collection of data for dentulous subjects:

For each patient, maxillary and mandibular impressions with irreversible hydrocolloid material made in suitable perforated stock metal tray. The impressions were poured in type III gypsum product, dental stone.

Facebow transfer of the patient was done with ear piece type facebow (Bio-art professional facebow). Maxillary cast was mounted on semiadjustable, arcon articulator (Bio-art A7 Plus). Interocclusal record was made and mandibular cast was articulated in centric relation record.

Maxillary cast from the upper member was removed. Supporting rode of the articulator was removed and customised occlusal plane analyzer was attached to the upper member of the articulator.

The anterior survey point was the incisal tip of the lower canine tooth, and the posterior survey point was anterior most point of condylar element of the articulator[24]. Because of the structure of condylar element of the articulator it was possible to locate the point accurately. From these two point arcs of the 4 inches were made towards the upper member of the articulator. The intercept of these arcs was used to determine the centre of a circle, which would be drawn to lie against the points on the lower canine and condylar element already described. The curve derived in this way is the one which dictated theoretically ideal occlusal plane.

The distances between two curves, namely existing occlusal plane and theoretically ideal broadrick occlusal plane, were measured at four points with digital vernier caliper. The four predetermined points were buccal cusp tip of left mandibular first premolar (Point 1), buccal cusp tip of left mandibular second premolar (Point 2), mesiobuccal cusp tip of left mandibular first molar (Point 3) and mesiobuccal cusp tip of left mandibular second molar (Point 4).

Where the deviation was outside the existing curve a positive notation was given, if the deviation was inside the curve a negative notation was given. If the derived curve was inside the established curve, autopolymerising acrylic stent was fabricated on the occlusal surface of the posterior teeth and derived curve was scribed on the surface of stent. Where no deviation was detected a value of zero was awarded. Results were tabulated.

For edentate patient:

Making primary and secondary impressions and casts:

For each individual, primary impressions were made by impression compound and primary models were poured in Type II dental plaster. The custom trays were fabricated using autopolymerising acrylic resin by dough method.

The secondary impressions were made using tracing compound and metallic oxide impression paste in conventional manner. The selective pressure impression technique was followed for impression making. Following beading and boxing, master casts were obtained in Type III dental stone.

Making record bases and wax occlusal rims:

After adequate block-out for undercuts, temporary record bases were fabricated using autopolymerising acrylic resin. The method followed for record base fabrication was sprinkle-on technique. For all cases, bite rims were fabricated using modeling wax. The conventional guidelines for bite rims dimensions were followed.

Establishing occlusal plane by anatomical method:

First, the occlusal plane was established in mandibular occlusal rim considering anatomical landmarks by following method advocated by **Zarb and Bolender**[47]. Anteriorly the plane of occlusion was established in level with the lower lip and the corner of the mouth in a relaxed state. As the plane goes posteriorly, the occlusal plane was made at the level of lateral border of the tongue. At the posterior end, the plane of occlusal rim was maintained at the level of anterior two thirds of the retromolar pad. The retromolar pad areas were marked on both right and left side on madibular arch. The marked retromolar pad areas were divided into three parts and

corresponding points were marked on the nonanatomical areas of the casts. By considering these markings the plane of occlusion was established in posterior part at the level of two thirds of the height of retromolar pad. The plane established in this manner was confirmed intraorally. Once the mandibular plane was established, the maxillary occlusal rim was altered in such a way that both bite rims would contact each other evenly. The maxillary bite block was reduced until sufficient freeway space had been obtained in rest position of the mandible.

Facebow transfer and mounting of maxillary cast on articulator:

The bite fork was fixed to the maxillary occlusal rim. The rigidity of the junction was verified. By adjusting intercondylar distance of the facebow frame, nasion locator and stem of the bitefork, orientation jaw relation was obtained. By using transfer jig assembly, the relation was transferred to the articulator and mounting of the maxillary cast was done.

Making of interocclusal record and mounting of mandibular cast on the articulator:

The mandible was guided in the centric relation. The relation was verified and bite rims were fused. The mandibular cast was mounted on the articulator according to the centric jaw relation recorded earlier. The anterior teeth set for the patient was selected according to intercanine distance.

Teeth setting and wax trial:

The setup for the artificial teeth was started with maxillary anterior teeth, which was followed by mandibular anterior teeth. The mandibular canine position was standardized for all patients. The straight lines indicating crest of alveolar bone were drawn in mandibular posterior and anterior segments, one in each. The junctions of the lines of anterior and posterior segments were standardized as canine position. Anterior trial was done to verify the position of the mandibular canine as far as phonetics and esthetics are concern.

The mandibular posterior teeth were set according to the line in the respective segment. The maxillary posterior teeth were set in proper occlusion with mandibular teeth. Required adjustments were done to obtain teeth positions as per setting principles. The wax trial was approved after considering phonetics, esthetics, vertical dimension, free way space and other parameters.

Occlusal plane analysis:

Maxillary cast, along with trial denture, was removed from the upper member. Supporting rode of the articulator was removed and customised occlusal plane analyzer was attached to the upper member of the articulator. Center position of the analyzer was verified in relation to the upper member.

The anterior survey point was the incisal tip of the lower canine prosthetic tooth, and the posterior survey point was anterior most point of condylar element of the articulator[24]. From these two point arcs of the 4 inches were made towards the upper member of the articulator and occlusal plane analysis was done similar to the dentate part of the study. The distances between two curves, namely anatomically

established occlusal plane and theoretically ideal broadrick occlusal plane, were measured at four points with digital vernier caliper. The four predetermined points were buccal cusp tip of mandibular left first premolar, buccal cusp tip of mandibular left second premolar, mesiobuccal cusp tip of mandibular left first molar, mesiobuccal cusp tip of mandibular left second molar.

Where the deviation was outside the existing curve a positive notation was given, if the deviation was inside the curve a negative notation was given. If the derived curve was inside the established curve, autopolymerising acrylic stent was fabricated on the occlusal surface of the posterior teeth and derived curve was scribed on the surface of stent. Where no deviation was detected a value of zero was awarded. Results were tabulated.

Staistical analysis:

Mean and Standard deviation of the values obtained for each group

One-way ANOVA

PHOTOGRAPHS

Armamentarium

1(A). Armamentarium for Examination

1(B). Armamentarium for impression making for dentate patients

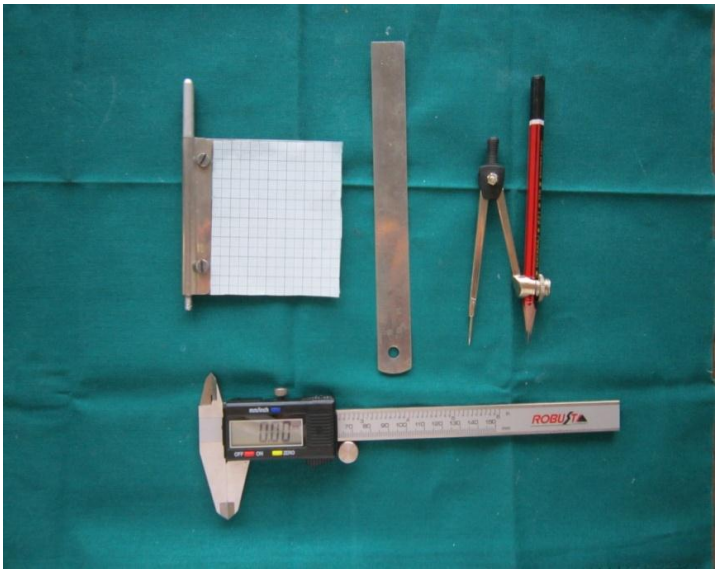
2(A). Armamentarium for impression making for edentate patients

2(B). Armamentarium for jaw relation for edentate patients

3(A). Bio-art A7 Plus Articulator

3(B). Bio-art Professional Face-bow with transfer jig and bite fork

4(A) Armamentarium for occlusal analysis

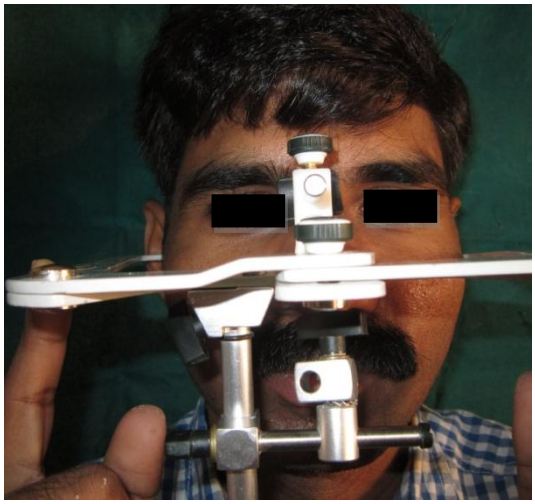


4(B) Digital vernier caliper

Clinical Procedure for Dentate Patient

5(A) Alginate impressions for dentate patient

5(B) Face-bow recording



6(A) Face-bow transfer record

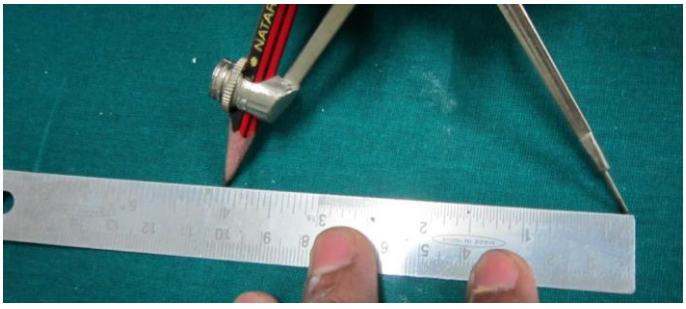
6(B) Jig transfer

7. Face-bow transfer on articulator

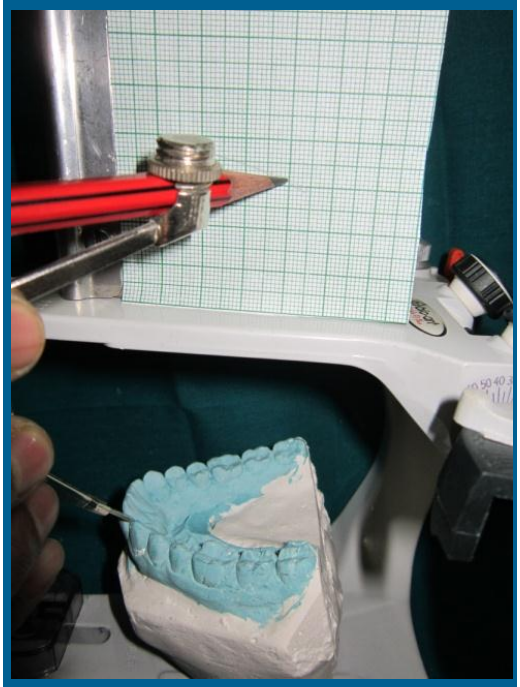
8(A) Mounting of maxillary cast

8(B) Mounting of mandibular cast

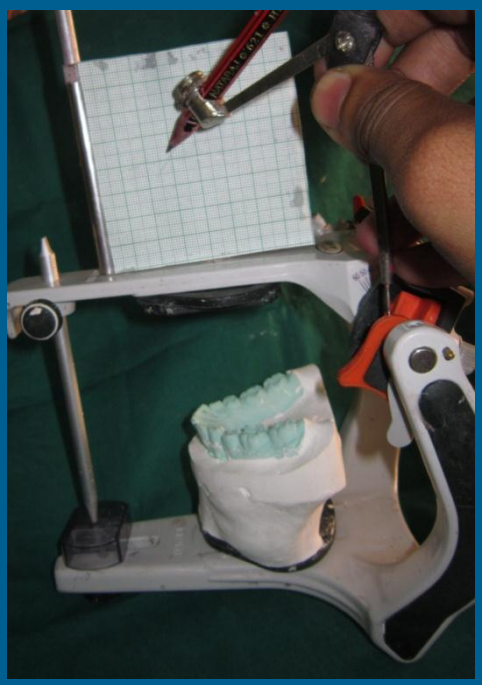
9. 4-inch measurement on compass



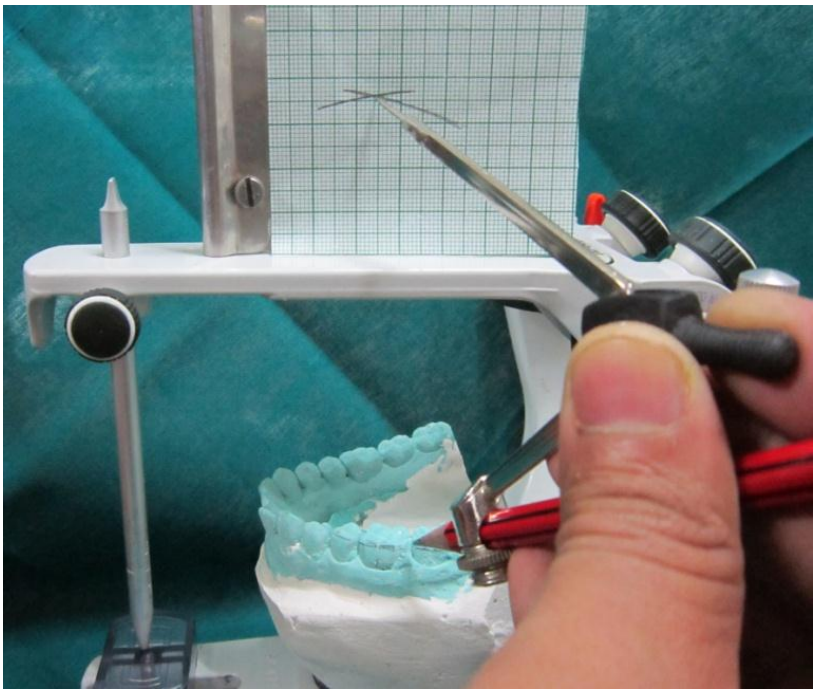
10. Occlusal analysis (ASP)



11 Oclusal analysis (PSP)



12. Occlusal analysis



13(A) Derived theoretically ideal occlusal plane

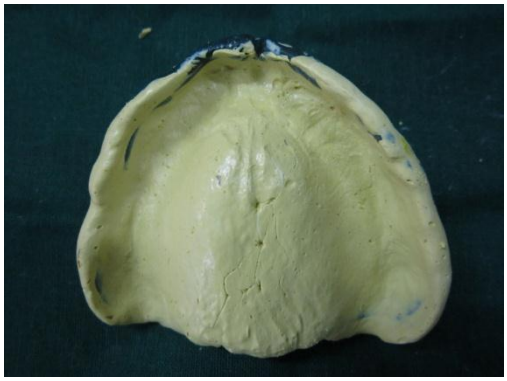
13(B) Stent for derived plane above the existing occlusal plane

14. Measurement of deviation using digital vernier caliper

Clinical Procedure for Edentate Patient

15. Primary impressions

16. Secondary impressions



17. Anterior Mandibular plane establishment

18. Marking for retromolar pad on cast

19. Face bow recording

20. Face-bow transfer

21. Canine position standardization

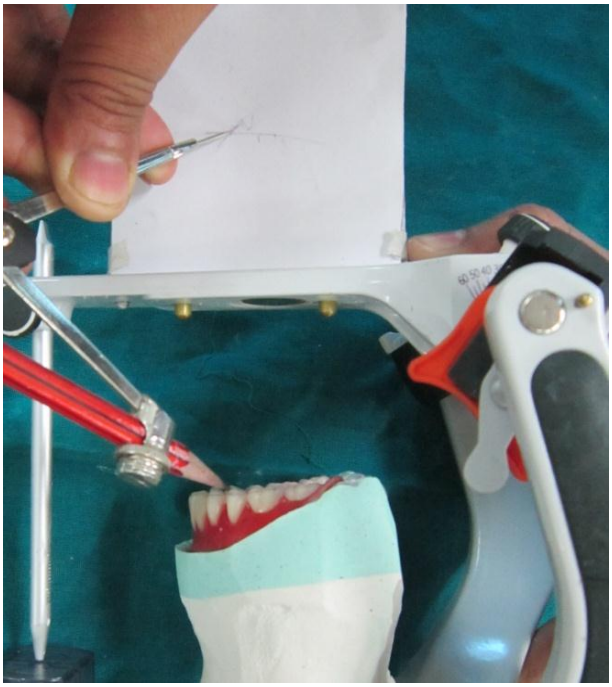
22. Maxillary and Mandibular teeth setting

23(A).Teeth setting (saggital view)

23(B). Teeth setting (Frontal view)

24. Occlusal analysis

25. Theoretically ideal occlusal plane



26. Theoretically ideal occlusal plane

RESULTS

The clinical study was carried out to measure the deviation of existing occlusal plane of dentate patient and anatomically established occlusal plane of edentate patient from theoretically ideal occlusal plane derived by occlusal plane analysis. Both dentate and edentate occlusal plane were compared to the theoretically ideal occlusal plane.

The individuals under study were divided into two groups, namely dentulous and completely edentulous, as per their oral condition. Each group had 10 samples. So total no of 20 patients were included in the study.

For dentate group, sample size 10, differences between existing occlusal plane and theoretically ideal broadrick occlusal plane were measured at four points. The four points were buccal cusp tip of mandibular left first premolar (Point 1), buccal cusp tip of mandibular left second premolar (Point 2) , mesiobuccal cusp tip of mandibular left first molar (Point 3) and mesiobucaal cusp tip of mandibular left second molar. The measurements were made on left side of the jaws.

For edentate group, sample size 10, differences between anatomically established occlusal plane and theoretically ideal broadrick occlusal plane were measured at four predetermined points.

The numerical values obtained by measurements are shown in Table 1 and Table 2 for both dentate and edentate groups, respectively. The graphic presentation for the same is fig.1 and fig. 2, respectively

Table 3 presents Mean and Standard deviation for dentate group. Based on these values, table 4 shows level of significance for dentate group which has been calculated by using One-way ANOVA.

Table 5 shows Mean and Standard deviation for edentate group of the individual. Table 6 describes level of significance for edentate group.

Table 7 and Table 8 describe mean difference for each patient in both dentate and edentate groups, respectively.

Table 1: Basic values obtained for differences between existing occlusal plane and theoretically ideal Broadrick occlusal plane in dentate patients

	Point1	Point2	Point3	Point4
Pt1	1.14	1.53	2.03	1.78
Pt2	0.71	-0.43	-1.19	-1.33
Pt3	0.0	0.0	0.0	0.0
Pt4	0.49	0.73	1.36	1.13
Pt5	0.0	0.0	-0.25	-0.62
Pt6	1.03	1.32	0.46	0.0
Pt7	0.58	0.93	0.37	-0.77
Pt8	0.0	0.51	0.76	0.49
Pt9	0.39	0.56	0.76	1.12
Pt10	-0.27	-0.70	-0.88	-0.88

Table 2: Basic values obtained for differences between anatomically established occlusal plane and theoretically ideal Broadrick occlusal plane in edentate patients

	Point1	Point2	Point3	Point4
Pt1	-0.52	-0.75	-1.28	-1.43
Pt2	0.58	1.24	1.72	1.35
Pt3	1.16	1.59	1.76	1.97
Pt4	0.29	0.55	0.68	0.46
Pt5	1.25	1.57	1.82	2.12
Pt6	-0.27	-0.69	-0.85	-1.16
Pt7	0.35	0.76	1.16	0.83
Pt8	1.32	1.75	1.66	1.27
Pt9	0.26	0.45	0.83	1.15
Pt10	-0.45	0.00	0.52	0.76

Table 3: Mean and Standard deviation values for dentate group for observations made at predetermined points

		Mean	SD
Point	**Point 1**	0.41	0.47
	Point 2	0.45	0.73
	Point 3	0.34	0.98
	Point 4	0.09	1.02

Table 4: One-way ANOVA for dentate group

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.757	3	0.252	0.368	0.777
Within Groups	24.692	36	0.686		
Total	25.449	39			

Table 5: Mean and Standard deviation values for edentate group for observations made at predetermined points

		Mean	SD
Point	**Point 1**	0.40	0.69
	Point 2	0.65	0.91
	Point 3	0.80	1.10
	Point 4	0.73	1.19

Table 6: One-way ANOVA for edentate group

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.937	3	0.312	0.319	0.811
Within Groups	35.223	36	0.978		
Total	36.160	39			

Table 7: Mean of the differences between existing occlusal plane and theoretically ideal occlusal plane for each sample of dentate group

Patients	Mean of differences
Pt 1	1.62
Pt 2	-0.56
Pt 3	0
Pt 4	0.9275
Pt 5	-0.2175
Pt 6	0.7025
Pt 7	0.2775
Pt 8	0.44
Pt 9	0.7075
Pt 10	-0.6825
Mean	0.3215
Standard deviation	0.7104

Table 8: Mean of the differences between anatomically established occlusal plane and theoretically ideal occlusal plane for each sample of edentate group

Patients	Mean of differences
Pt 1	-0.995
Pt 2	1.2225
Pt 3	1.62
Pt 4	0.495
Pt 5	1.69
Pt 6	-0.7425
Pt 7	0.775
Pt 8	1.5
Pt 9	0.6725
Pt 10	0.2075
Mean	0.6445
Standard Deviation	0.9400

Interpretation of the results

Table 3 and fig. 3 describes the mean values for the differences between existing occlusal plane and theoretically ideal Broadrick occlusal plane for dentate group of the individual.

The point 4 has least mean value of 0.09 with standard deviation of 1.02. For point 3, the mean value is 0.34 with standard deviation of 0.98. The point 2 has highest mean value of 0.45 among all four points evaluated, followed by point 1 which has mean value of 0.41.

Based on these values, table 4 shows calculation of level of significance by using One-way ANOVA. The level of significance for the dentate group was 0.777 which is statistically not significant.

Table 5 and fig. 4 describes the mean values for the differences between anatomically established occlusal plane and theoretically ideal Broadrick occlusal plane for edentate group of the individuals.

Among all four points, for Point 1 mean value of difference between two planes is least which is 0.40 with standard deviation of 0.69, followed by point 2 with mean of 0.65 and standard deviation of 0.91 and point 4 which has mean value of 0.73 with standard deviation of 1.19. The highest mean value of 0.80 was observed for point 3 which has standard deviation of 1.10

The calculation of level of significance by using One-way ANOVA for edentate group is shown in table 6. The *p* value of 0.811 was obtained which was not significant statistically.

Table 7 and fig. 5 shows the mean values of differences observed at four different points for each sample of dentate group. The range for the values is from -0.6825 to 1.62. The mean for the values is 0.3215 with standard deviation of 0.7104.

Table 8 and fig. 6 describes the mean values for the deviation of anatomically established occlusal plane from theoretically ideal one for samples of edentate group. The value ranges from -0.995 to 1.69. The mean for the data is 0.6445 with standard deviation of 0.9400.

DIAGRAMS

Fig. 1: Basic values obtained for differences between existing occlusal plane and theoretically ideal Broadrick occlusal plane in dentate patients

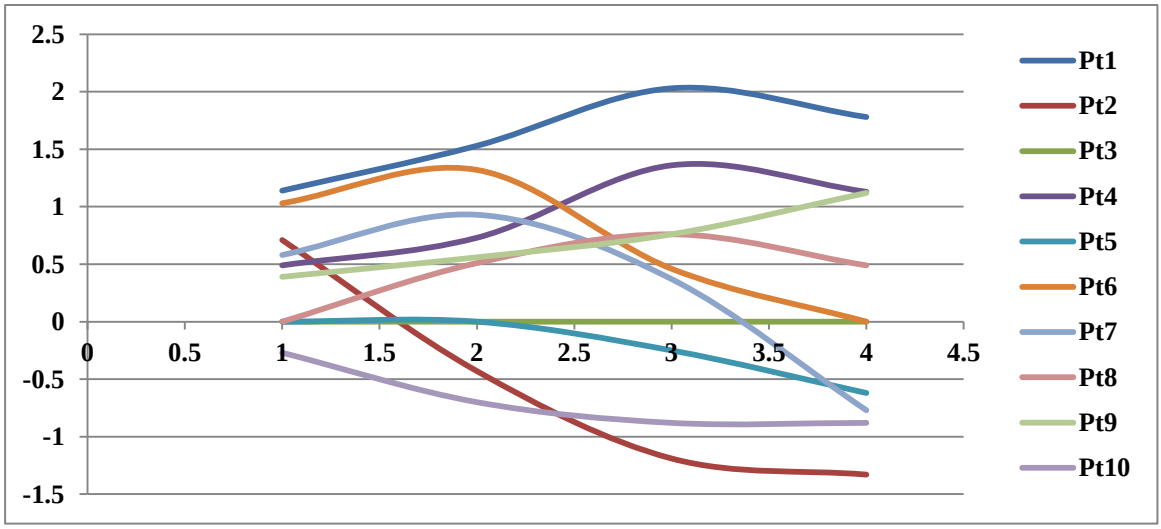


Fig 2: Basic values obtained for differences between anatomically established occlusal plane and theoretically ideal Broadrick occlusal plane in edentate patients

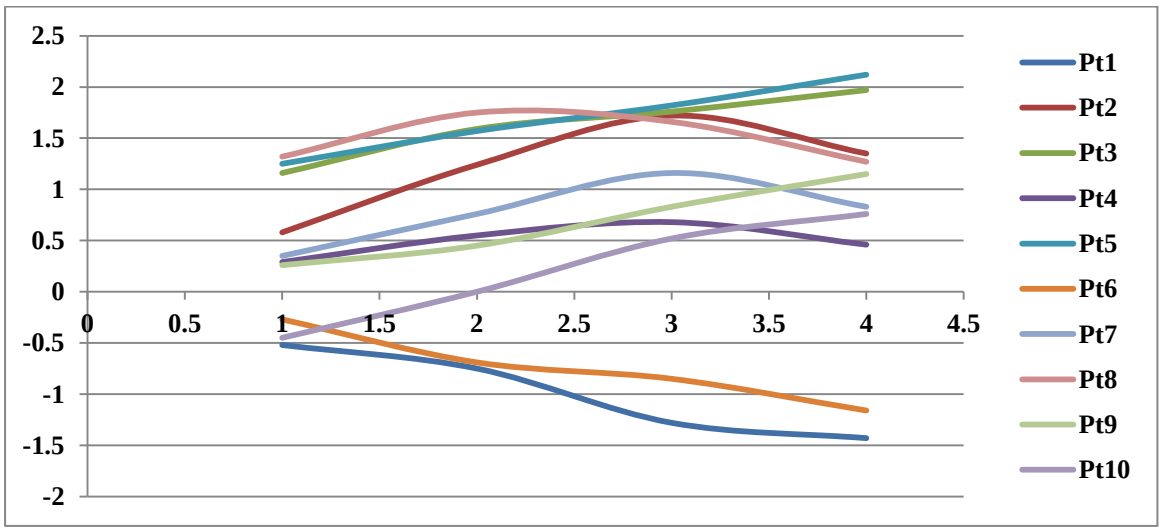


Fig 3: Mean and Standard deviation values for dentate group for observations made at predetermined points

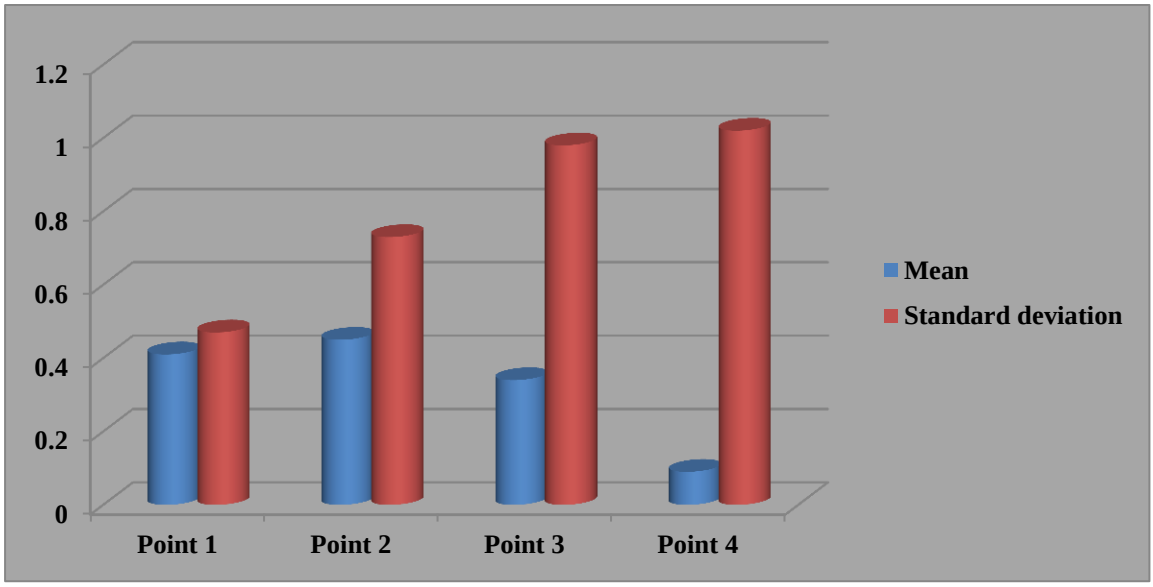


Fig 4: Mean and Standard deviation values for edentate group for observations made at predetermined points

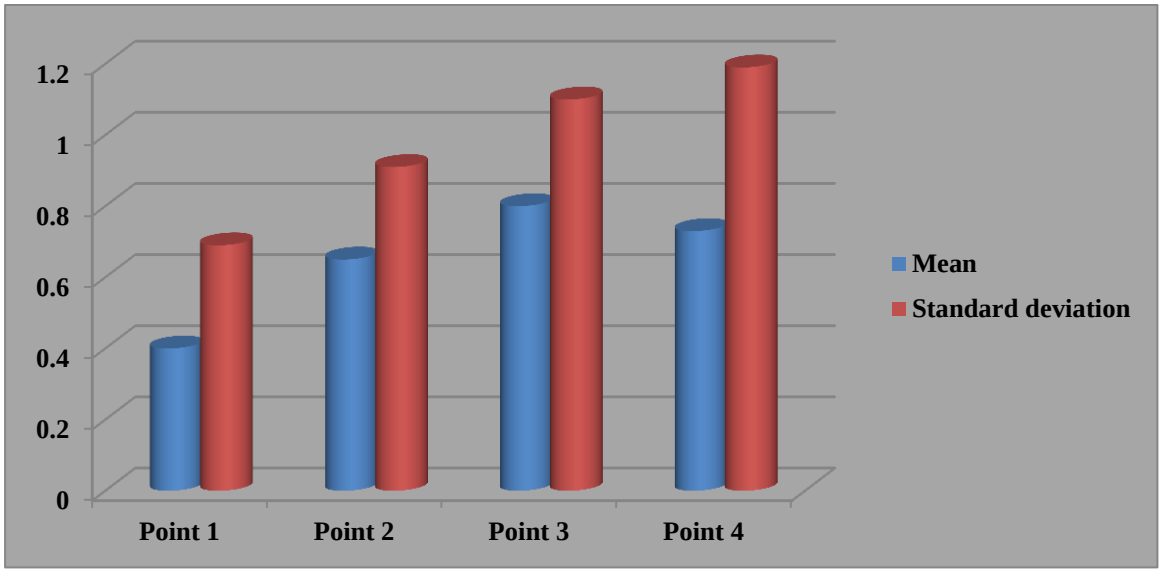


Fig 5: Mean of the differences between existing occlusal plane and theoretically ideal occlusal plane for each sample of dentate group

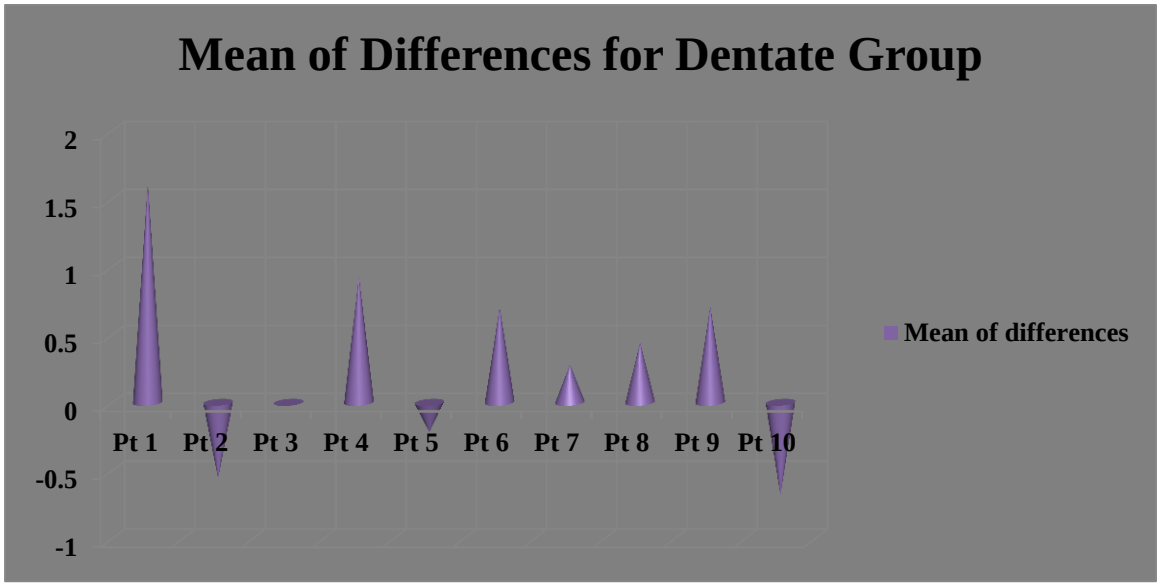
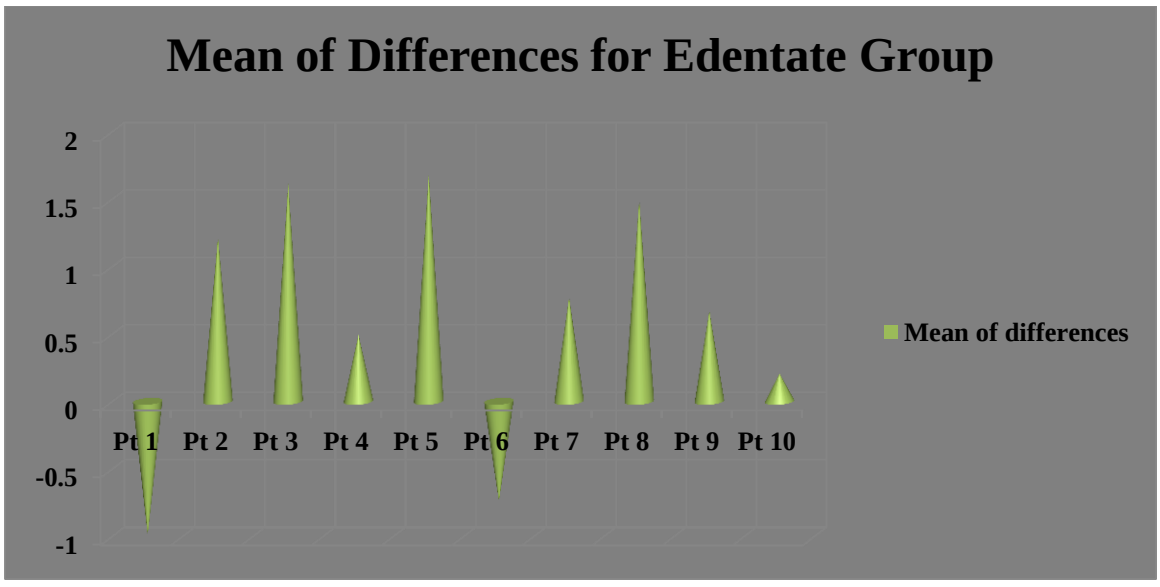


Fig 6: Mean of the differences between anatomically established occlusal plane and theoretically ideal occlusal plane for each sample of edentate group



DISCUSSION

The ultimate goal of any type of prosthodontic rehabilitation is to restore the missing structures in a way that they were present. To achieve this goal majority prosthodontic concepts have been derived from the observation made in healthy subjects. The concepts derived in this way will make successful rehabilitation possible in majority of the patients.

The concept for occlusal plane orientation is one such concept. In literature several authors have proposed their method for establishing occlusal plane, for both partially and completely edentate patients. In case of partially edentulous patients the most commonly used three methods are:

1. Direct analysis on natural teeth through selective grinding
2. Indirect analysis of facebow-mounted casts with properly set condylar paths
3. Indirect analysis using the Pankey- Mann-Schuyler (PMS) method with the Broderick occlusal plane analyzer

In case of complete denture patients the methods proposed are:

1. Parallel to ala-tragus line
2. Locating occlusal plane parallel to and midway between the residual ridges.
3. Positioning occlusal plane at the level of lateral border of the tongue
4. Locating occlusal plane posteriorly at the middle or upper third of the retromolar pad
5. Orienting occlusal plane with the buccinators grove and commissures of the lips.
6. Establishing occlusal plane in relation to parotid papilla
7. Use of certain cephalometric criteria for establishing occlusla plane

During complete denture construction the occlusal plane should be established as close to the natural dentition as possible. This statement is logical since the musculature of the tongue and cheeks was trained to function normally in that environment and will again function appropriately when they are called upon to stabilize the bolus at the same vertical position of the occlusal table as formerly existed[17].

For partially edentulous patient, the Broadrick occlusal plane analyzer method for occlusal plane orientation is widely accepted. The plane obtained by this method will have curvature as observed in sagittal plane, known as curve of Spee. For complete denture cases, still the opinion of the authors differs. In complete denture cases, as per the established occlusal plane, teeth setting will be done; following principles of the teeth setting. At this time the teeth set in trial denture will show curvature in sagittal plane. The curve, anteroposterior compensatory curve, established in this way will help to achieve balanced occlusion for better stability of the dentures. If the compensatory curve also has geometry similar to the curve of Spee of natural dentition, than the same method used for natural dentition may have potential to be used in complete denture fabrication also.

With this basic idea the present study was designed in two parts:

1. To check the validity of the Broadrick occlusal plane analyzer method for Indian dentate individuals
2. To measure deviation of conventionally established occlusal geometry with that derived by Broadrick occlusal plane analyzer method, if any.

The main idea behind the study was to investigate the applicability of the occlusal plane analyzer for the edentate patient to establish the plane of occlusion. In

the first part of the study, which involved dentate subjects, validity of the occlusal plane analyzer concept was assessed for dentate patients. In the second part the difference between the anatomically established occlusal plane and theoretically ideal occlusal plane was recorded. If the values for this difference are clinically and statistically not significant than occlusal plane analyzer can be proposed as a method for occlusal plane establishment.

The study included total of 20 individuals which includes 10 completely dentate and 10 completely edentate patients who came to the Department of Prosthodontics.

The articulator used in the study was Bio-art, model A7 plus articulator. The type of articulator is arcon semiadjustable. The articulator has adjustable intercondylar distance. The Bio-art articulator and Face-bow use nasion as third reference point. The face-bow used in the study was Bio-art, model Professional face-bow. This face-bow is of arbitrary, ear piece type. The main feature of this face-bow is jig transfer assembly which makes face-bow transfer easy and accurate. The articulator does not have accessory for occlusal plane analysis.

To overcome this difficulty, custom-made occlusal plane analyzer was planned. For fabrication of custom occlusal plane analyzer method proposed by **Sumit Bedia *et al*** [26] was considered. The supporting rod of the articulator, which is going to attach to the upper member of articulator, was duplicated. The 0.5 mm thick piece of stainless steel, sized 11cm×10cm was adapted to the rod and was fixed with the help of screws. The fixation was assessed for rigidity. The original supporting rod was removed and replaced by the duplicated one along with piece of metal in position. The assembly was fixed in such a way that the piece of metal lies exactly in

the middle of the upper member of the articulator. On both the surfaces of the stainless steel piece, graph paper was fixed and used for occlusal plane analyses.

Various authors have studied the curve of Spee on standardized digital images of the dental casts or scanned images of the dental cast[26, 18]. Such studies have documented geometry of occlusal plane in two-dimension. In the present study the geometry of occlusal plane was studied on actual three dimensional casts. The method used in study is similar to the method followed by **Supriya Manvi and coworkers**[29] in 2012. In the proposed method the measurements were made arbitrarily. In the present study, digital vernier caliper has been used for data collection. The advantage of the method is it gives accurate measurements on actual objects which can be considered as more reliable for clinical application when compared to the one made on standardized images, scanned images of the articulated models or cephalometric radiographs.

Comparison of existing occlusal plane of dentate patients to the broadrick occlusal plane:

For dentate group of the study, samples were obtained by following the criteria given by Ferrario. The models were obtained and after clinical and laboratory procedures maxillary and mandibular casts were mounted on the arcon semiadjustable articulator. For occlusal analysis, anterior survey point was taken as mid-point of distal incline of left mandibular canine and posterior survey point was the anterior most point of condylar element of the articulator[24]. For study purpose only left sides of the jaws were considered[24].

The distances between the cusp tip and line indicating broadrick occlusal plane were measured by digital vernier caliper. The reason for selecting this instrument for measurement is its accuracy and ease of use.

For dentate group of the present study, after tabulating the data obtained from the observations, mean values for the differences of the planes at specific point were obtained. The values for the Point1, Point 2, Point 3, and Point 4 were 0.41, 0.45, 0.34, and 0.09, respectively. For each point Standard deviations were 0.47, 0.73, 0.98, and 1.02. The values were not significant clinically. The statistical analysis by One-way ANOVA indicated *p* value of 0.777 which was statistically non-significant. This indicated that the existing occlusal plane of the individuals under study had not showed clinically and statistically deviation from the theoretically ideal broadrick occlusal plane. Hence it was considered that clinically, the existing occlusal plane of the dentate individual is similar to the theoretically ideal broadrick occlusal plane. The results of the study were in accordance with following authors:

George Monson[9] proposed the geometry of occlusal plane in form of sphere which has radius of 4-inch

Ferrario *et al* [15] analyzed three dimensional structure of the occlusal plane and concluded that the radii of the overall sphere, involving curve of Spee and curve of Wilson in the molar area were 105 mm in men and about 100mm in women.

Craddock *et al*[27] documented that the existing occlusal plane of the dentate individual had insignificant deviation from broadrick occlusal plane. In his study he found 55 patients among 100 Caucasian patients did not have any deviation from the theoretically ideal occlusal plane. In the present study among 10 Indian patients only 1 patient presented with the occlusal palne exactly similar to theoretically ideal

occlusal plane. The reason behind this observation may be the difference in the body dimensions as dictated by differences in races examined. The literature had indicated that there is a racial difference in the dentoalveolar component of Asians which shows more proclined upper incisors compared with Caucasians subjects[48].

Supriya Manvi and coworkers[29] reported close relation of the broadrick occlusal plane to the existing occlusal plane of the Indian dentate individuals.

Jagadeesh KN *et al* [30]varified reliability of the various radii for Skeletal Class I, II and III jaw relations. They supported view proposed by Lynch and McConnell and advocated use of 3.75-inch for Class II individuals, 4-inch for Class-I and 5-inch radius for Class III. In the present study for Class I skeletal relation, 4-inch radii was used.

Comparison of anatomically established occlusal plane of edentate patient to the broadrick occlusal plane:

For edentate group of the study, the samples were selected with Class-1 skeletal relation observed at the time of diagnostic mounting. Class 2 and Class 3 skeletal relations were not included in the study because of marked difference in the geometry of occlusal plane.

For all subjects, clinical and laboratory steps of the complete denture fabrication were followed in conventional manner till the articulation of the casts on the arcon, semiadjustabe articulator.

For the study, size and positions of the anterior teeth were of importance to obtain proper esthetics and phonetics. For all cases the teeth set were selected

according to intercanine distance. The mandibular canine, being anterior survey point, was important for the study. There was a need to standardize the position of the mandibular canine. The straight lines indicating crest of alveolar bone were drawn in mandibular posterior and anterior segments, one in each. The junctions of the lines of anterior and posterior segments were standardized as canine positions on both the sides of the arches. The remaining posterior teeth were set according to setting principles.

The statistical analysis of the tabulated data showed mean values for Point1, Point 2, Point 3, and Point 4 as 0.40, 0.65, 0.80 and 0.73, respectively. The Standard deviations were 0.69, 0.91, 1.10 and 1.19, respectively. The *p* value of 0.811 was obtained by using One-way ANOVA. The differences between two planes obtained from the observations made during study were not significant clinically. By statistical analysis indicated *p* value of 0.811 which was statistically non-significant.

There is lack of documentation regarding use of Broadrick occlusal plane analyzer for completely edentulous patients in the literature reviewed. To the best of author's knowledge there is no literature to propose the use of Broadrick occlusal plane concept for edentate patients. Due to lack of literature, there is no comparable data to substantiate the results obtained in the study.

The study has shown the relation between the anatomically established occlusal plane and broadrick occlusal plane as far as geometry of the occlusal plane is concerned. But before applying these results in clinical practice, certain aspects should be considered, which are as follow.

(1) The present study has compared only geometry of two occlusal planes. Before the proposed method is used for clinical cases other parameters should also be

evaluated. The phonetics and esthetics achieved by the proposed method of occlusal plane should be studied. More importantly, with proposed method possibility for achieving bilateral balancing during eccentric movements in complete denture should be investigated.

(2) As **Peter Dowson** documented, the anteroposterior curve, curve of Spee will have tendency to disocclude the posterior teeth during protrusive movement, at given incisal guidance. According to above mentioned statement it is not possible to achieve balancing with the geometry of occlusal plane which resembles curve of Spee.

The solution to this problem lies in the literature which documented the use of occlusal plane analyzer for the first time in full mouth rehabilitation. **Pankey and Mann** first proposed the use of occlusal plane analyzer and incorporation of the occlusal plane derived in this way for full mouth rehabilitation. Initially, Pankey and Mann advocated bilateral balanced occlusion scheme with the occlusal plane they proposed[10]. Later, **Shuyler** reported ill effects of lateral forces to the natural teeth and modified the method to avoid balancing contacts[48]. This indicates that with modification in incisal guidance, cusp height and cusp angulations, it is possible to establish bilateral balancing during eccentric movements for complete denture.

Moreover, occlusal plane analyzer is documented method to establish occlusal plane for cases requiring single complete denture where the method is used to provide balanced occlusion in eccentric movements.

(3) In the present study, for edentate group cases with Class-I skeletal jaw relation were included. Moreover, sample size of the study was limited to 10. The

future clinical trials should be carried out on bigger sample size and should include wide variety of samples with anatomical variations.

(4) To use the proposed method for establishing posterior occlusal plane, anterior wax trial should be approved to verify the position of the mandibular canines. Later, mandibular canine can be taken as anterior survey point and further occlusal plane analysis should be carried out.

SUMMARY AND CONCLUSSION

In spite of research for years together, prosthodontists have been trying to find out the ideal geometry configuration of occlusal plane during complete denture fabrication. Over a period of years, researchers have documented their ideas and philosophies for occlusal plane in complete denture fabrication. But still there is a lack of accurate, easy and clinically applicable method for occlusal plane establishment for complete denture patients.

Moreover, validity of widely accepted broadrick occlusal plane analyzer has not been assessed for Indian population.

Hence this study was done to evaluate validity of broadrick occlusal plane analyzer method for Indian dentate population and to investigate whether the broadrick occlusal plane analyzer method of determining occlusal plane can be used for complete denture patients. The study was conducted in Department of Prosthodontics, Tamilnadu Government College and Hospital, Chennai. The study involved 10 dentulous and 10 edentulous patients. The study results indicated:

(1) The deviation of existing occlusal plane of dentate individuals from theoretically ideal broadrick occlusal plane was found to be non-significant clinically and statistically.
(2) The anatomically established occlusal plane for edentate patient had geometry which was in close resemblance to the geometry of theoretically ideal broadrick occlusal plane.

Within the limitation of the present study it can be concluded that:

(1) The broadrick occlusal plane analyzer method of establishing occlusal plane is valid for the Indian population

(2) The broadrick occlusal plane analyzer may have potential to be used in fabrication of complete denture for establishing posterior occlusal plane.

The future study should include large sample size with anatomical variations and should consider clinical applicability and related aspects for the proposed method.

BIBLIOGRAPHY

1. Dawson PE, Evaluation Diagnosis and Treatment of Occlusal Problems St. Louis, Mo.:Mosby; 1989 pg. 86-87.
2. GPT 8
3. Bedia SV, Dange SP, Khalikar AN. Determination of the occlusal plane using a custom-made occlusal plane analyzer: A clinical report. J Prosthet Dent 2007;98:348-352
4. Sehgal MM, Kapur S, Arora A. A custom made occlusal plane analyzer for determining the occlusal plane- A clinical report. Journal of Orofacial and Health Sciences. 2012 vol 3 iss 2
5. Small BW. Occlusal plane analysis using the Broadrick flag. Gen Dent 2005;53:250-2.
6. Chaturvedi S, Verma AK, Ali M, Shah M. Full mouth rehabilitation using a custom-made broadrick flag: A case report. Int J Case Reports Images 2012 ; 3 : 41-44
7. Senthilkumar KP, Tamizharasi S. Significance of curve of Spee: An Orthodontic Review. Journal of Pharmacy and Bioallied Sciences. 2012 ; vol 4 : issue 3 supplement 2 Page S323
8. Spee FG, Biedenbach MA, Hotz M, Hitchcock HP. The gliding path of the mandible along the skull. J Am Dent Assoc 1980; 100:670-5.
9. Monson GS. Occlusion as applied to crown and bridgework. J Nat Dent Assoc 1920:7; 399-413.
10. Becker CM, Kaiser DA. Evolution of occlusion and occlusal instruments. J Prosthodont 1993; 2:33-43.
11. Orthlieb J-D. The curve of Spee: understanding the sagittal organisation of mandibular teeth. J Cranio. 1997; 15: 333–340.

12. Ash M. M. In: Wheeler" Dental Anatomy,Physiology and Occlusion 7th edn., pp. 88-89; 420 423. W. B. Saunders Co., Philadelphia, PA.
13. Osborn J. W. Orientation of the masseter muscle and the curve of Spee in relation to crushing forces on the molar teeth of primates. Am. J. Phys. Anthropol. 92, 99-106.
14. Farella M, Michelotti A, van Eijden TMGJ, Martina R. The curve of Spee and craniofacial morphology: a multiple regression analysis. Eur J Oral Sci 2002; 110: 277–281
15. Ferrario VF, Sforza C, Miani A. Statistical evaluation of Monson's sphere in healthy permanent dentition in man. Archs oral Biol. 1997Vol. 42, No. 5, pp. 365-369
16. Hui Xu, Toshihiko Suzuki, Motoo Muronoi, Kiyoshi Ooya. An evaluation of the curve of Spee in the maxilla and mandible of human permanent healthy dentitions. J Prosthet Dent 2004; 92:536-9.
17. P.-S. Fu, C.-C. Hung, J.-M. Hong & J.-C. Wang. Three-dimensional analysis of the occlusal plane related to the hamular–incisive–papilla occlusal plane in young adults. Journal of Oral Rehabilitation 2007 34; 136–140
18. Jayachandran S, Ramachandran CR, Varghese R. Occlusal plane orientation: A statistical and clinical analysis in different clinical situations. Journal of Prosthodontics 2008; 17: 572–575
19. Mann AW, Pankey LD. Part I. the use of the P-M instrument in treatment planning and restoring the lower posterior teeth. J Prosthet Dent 1960;10:135-50
20. Bowley JF, Stockstill JW, Attanasio R. A preliminary diagnostic and treatment protocol. Dent Clin North Am 1992;36:551-68

21. McLaughlin GL. Adaptation of an occlusal plane analyzer to a semiadjustable articulator. J Prosthet Dent 1972 ; 28 : 445-7
22. Denar SOPA instruction manual
23. Wynne William PD. Wynne 2000 occlusal plane analyzer. The art of articulation2005 vol 3 iss 1
24. Lynch CD, McConnell RJ. Prosthodontic management of the curve of Spee: Use of the Broadrick flag. J Prosthet Dent 2002; 87:593-7.
25. Toothaker RW, Graves AR. Custom adaptation of an occlusal plane analyzer to a semi-adjustable articulator. J Prosthet Dent 1999;81:240-2.
26. Bedia SV, Dange SP, Khalikar AN. Determination of the occlusal plane using a custom-made occlusal plane analyzer: A clinical report. J Prosthet Dent 2007;98:348-352
27. Craddock HL, Lynch CD, Franklin P, Youngson CC, Manogue M. a study of the proximity of the broadrick ideal occlusal curve to the existing occlusal curve in dentate patients. Journal of Oral Rehabilitation 2005 32; 895–900
28. Craddock HL, Youngson CC, Manogue M. Deviation from the broadrick occlusal curve following posterior teeth loss. Journal of Oral Rehabilitation 2006 33; 423–429
29. Manvi S, Miglani S, Rajeswari CL, Srivatsa G, Arora S. occlusal plane determination using custom made broadrick occlusal plane analyzer: A case control study.
30. Jagadeesh KN, Kashinatha HM, Bembalgi MS, Ramesh Kumar PC, Yarlagadda KB, Ateeq PM. Reliability of broadrick flag in determination of curve of spee in Indian population. J Contemp Dent Pract 2012;13(5):627-31
31. Misch CE. Dental implant prosthetics. 2005, Mosby Inc, Page 162-63

32. Sloane RB, Cook L. A guide for orientation of plane of occlusion. J Prosthet Dent. 1953 ; 3 :53-65
33. Hall WA. Important factors in adequate denture occlusion. J Prosthet Dent 1958 ; 5 : 764-775
34. Boucher CO. Discussion of “laws of articulation”. J Prosthet Dent 1963 ; 45-48
35. Ismail YR, Bowman JF. Position of the occlusal plane in matural and artificial teeth. J Prosthet Dent. 1968 ; 20 : 407-11
36. L’Estrange PR, Vig PS. A comparative study of the occlusal plane in dentulous and edentulous subjects. J Prosthet Dent 1975 ; 33 :495-503
37. Douglas JB, Meader L, Kaplan A, Ellinger C. Cephalometric evaluation of the changes in patients wearing complete dentures: A 20 year study. J Prosthet Dent 1983 ; 69 : 270-5
38. Tuncay OC, Thompson S, Abadi B, Ellinger C. Cephalometric evaluation of the changes in patients wearing complete dentures. A ten-year longitudinal study. J Prosthet Dent 1984 ; 2 : 169-180
39. Van Niekerk FW, Miller VJ, Bibby RE. The ala-tragus line in complete denture prosthodontics. J Prosthet Dent 1985 ; 53 : 67-69
40. Monteith BD. A cephalometric method to deterine the angulation of the occlusal plane in edentulous patients. J Prosthet Dent 1985 ; 54 : 81-7
41. Monteith BD. Evaluation of a cephalometric method of occlusal plane orientation for complete dentures. J Prosthet Dent 1986 ; 55 : 64-9
42. Karkazis HC, Polyzois GL. A study of the occlusal plane orientation in complete denture construction. J Oral Rehab 1987 ; 14 : 399-404

43. Karkazis HC, Polyzois GL.Cephalometrically predicted occlusal plane: Implicaiton in removable prosthodontics. J Prosthet Dent 1991 ; 65 : 258-64
44. Celebice A. A study of the occlusal plane orientation by intra-oral method. (Retromolar Pad). J Oral Rehab 1995 ; 22 : 233-6
45. Nissan J, Barnea E, Zeiter C. Cardash HS. Relationship between occlusal plane determinations and craniofacial structures. J Oral Rehab 2003 ; 30 : 587-9
46. Shigli K, Chetal BR, Jabade J. Validity of soft tissue landmark in determining the occlusla plane. J Indian Prosthodont Soc 2005 ; 5 : 139-45
47. Zarb-Bolender. Prosthodontic treatment for edentulous patients- completes dentures and implant supported prosthesis (12th edition). Saunders Co. 2004
48. Ishi N, Deguchi T, Hunt HP. Craniofacial differences between Japanese and British Caucasian females with a skeletal class III malocclusion. Europ J Ortho 2002 ; 24 : 493-99
49. Schuyler CH. Factors of occlusion applicable to restorative dentistry. J Prostho Dent. 1953; 3 : 772-82

APPENDICES

INFORMATION SHEET

 We are conducting a study on USE OF OCCLUSAL PLANE ANALYZER IN DENTULOUS AND EDENTULOUS INDIVIDUALS TO MEASURE DEVIATION FROM THEORETICALLY IDEAL OCCLUSAL PLANE device among patients attending TNGDCH, Chennai and for that study we are selecting patients.

 The privacy of the patients in the research will be maintained throughout the study. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

 Taking part in this study is voluntary. You are free to decide whether to participate in this study or to withdraw at any time; your decision will not result in any loss of benefits to which you are otherwise entitled.

 The results of the special study may be intimated to you at the end of the study period or during the study if anything is found abnormal which may aid in the management or treatment.

 For dentulous patients, impression of the maxillary and mandibular arch will be made. For each patient facebow transfer will be done and interocclusal record will be made. These records will be used for measuring predetermined data.

 For edentulous patients, after wax trial upper and lower trial dentures will be used for the collection of required data and processed dentures will be delivered to the patient.

Signature of investigator Signature of participant

Date:

INFORMED CONSENT FORM

Title of work:

USE OF OCCLUSAL PLANE ANALYZER IN DENTULOUS AND EDENTULOUS INDIVIDUALS TO MEASURE DEVIATION FROM IDEAL OCCLUSAL PLANE

Name: OP No:
Address: Case No:
Age:
Sex:

I, exercising my free power of choice, hereby give my concent to be included as a participant in the clinical study. I agree the following:

I have been informed to my satisfaction about the purpose of the study, nature of the treatment and study procedure.

I understand that dentist may stop my participation from clinical study for any reason. I am also aware of my right to opt out of the study at any time during the clinical study duration without giving any reason.

I hereby give my permission to use my records for research purpose and I am told that study institution and dentist will keep my identity confinedtial.

Name of the patient

Signature and Date