# COMPARATIVE EVALUATION OF FACIOLINGUAL INCLINATION OF MAXILLARY TEETH USING A CUSTOMIZED MOUNTED ANGLE PROTRACTOR WITH A CBCT EVALUATION SOFTWARE.

By

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**IN**

**ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS**

Under the guidance of

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2021-2024

## DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled **"Comparative evaluation of faciolingual inclination of maxillary teeth using a customized Mounted Angle Protractor with a CBCT evaluation software" is** a bonafide and genuine Research work carried out by me under the guidance of **Dr. Binnoy Kurian**, Professor & HOD, Department of Orthodontics & Dentofacial Orthopaedics, St.Gregorios Dental College, Kothamangalam.

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ABSTRACT

Orthodontic treatment aims to achieve proper faciolingual inclination of teeth by considering tooth anatomy, bracket placement, and torque application. Proper faciolingual inclination plays a significant role in creating a beautiful smile. The aim of this study was to develop a valid, reliable, and non-invasive method to record faciolingual inclination and compare it with the CBCT derived angulations.

**Background & Objectives:**

To estimate the faciolingual inclination of maxillary teeth using a Mounted Angle Protractor.

To compare the values obtained for the same patient with two CBCT values:

1. Crown inclination
2. Tooth inclination

To establish whether there are any significant changes in the values

**Materials and Methods:**

Pretreatment CBCT images and pretreatment casts of 30 patients were collected from Department of Orthodontics and Dentofacial Orthopaedics, St.Gregorios Dental College,Chelad, Kothamangalam. A custom made Mounted Angle Protractor was used to measure the faciolingual inclination on patient casts and the values obtained were compared with CBCT derived values.

**Results and Conclusion:**

The faciolingual inclination values obtained from the protractor was marginally less than the values obtained from CBCT but the difference was not statistically significant ($P > 0.5$). The findings of this study suggests that Mounted Angle Protractor is a reliable tool for measuring the faciolingual inclination.

**Keywords:**

Mounted angle protractor, faciolingual inclination, tooth inclination.

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# ***Introduction***

# INTRODUCTION

Orthodontics is the art and science of moving teeth and the associated bone with proper appliances from malocclusion to a stable occlusion with the best possible tooth alignment and function, a change that positively affects facial appearances.[1]

Among all the effort of perfecting the orthodontic appliances, probably few surpasses the contributions of Andrews,[2-5] who studied the stone models of 120 people with optimal tooth alignment and occlusion. He found that, in these subjects, the positions of the same types of teeth among different subjects fell within a narrow range. He also found six common features or “keys” that were shared by patients with optimal natural occlusions. Based on these studies, Andrews developed the concept, the treatment goal, and the design of the fully programmed appliances with built-in dimensional and angular features for each type of tooth. Since then, orthodontists have adopted various types of preadjusted appliances to carry out orthodontic treatment with minimum wire bending. Preadjusted appliances were intended not only to treat patients with less effort and more efficiency, but also to improve the quality of the orthodontic finishing.[6] However, even experienced orthodontists still found it difficult to achieve all six keys to normal occlusion using preadjusted appliances, mostly because of inaccuracies in bracket positioning during the initial bonding.[7] In addition, the prescriptions for most of these appliances are based on Andrews’s discovery made on the stone model crowns, and not enough attention has been given to the roots. As a result, precise positioning of the whole teeth including the roots at the end of the orthodontic treatment continues to be a challenge.[8-10]

In accordance with Andrews’s six keys to normal occlusion, there are six parameters that define the 3- dimensional position of each whole tooth: four of them (mesiodistal, faciolingual, and occlusogingival positions, and axial rotation) are dictated by the crown; but two others, mesiodistal angulation and faciolingual inclination, involve the root because of variations in crown morphologies,[8-11] inconsistencies in crown-root angulations,[11-13] and short crown length relative to root length. So, roots might also need to be assessed to achieve ideal whole tooth angulation and inclination.

Traditionally, panoramic radiographs have been used at the initial, progress, and finishing stages of orthodontic treatment to diagnose, monitor, and finalize the angulations of the teeth.[14,15] However, studies have indicated that panoramic radiographs have distortions and do not reflect the true 3-dimensional teeth angulations because the x-ray beam is not always orthogonal to the target teeth.[16-19] For faciolingual inclinations, the only assessment tool available is the lateral cephalogram for the maxillary and mandibular central incisors.[20,21] A posteroanterior cephalogram might capture the faciolingual inclinations of a few molars, but the image quality is usually poor and rarely used.

Measurement of the mesiodistal angulation and the faciolingual inclination of the whole tooth requires 3-dimensional images of the roots; these have become available only recently with the development and use of cone-beam computed tomography (CBCT) in orthodontics. This lets us accurately evaluate the mesiodistal angulation and the faciolingual inclination of each whole tooth (crown and root) rather than just the crown. The volumetric images obtained from cone-beam computed tomography (CBCT) scans show the dentofacial structures in a 1:1 ratio, and distortions, if any, are clinically insignificant.[22-24] However, a valid method or a clinically useful tool to directly measure the mesiodistal angulation and the faciolingual inclination of each whole tooth accurately is still lacking.

The aim of this study was to develop a valid, reliable, and non-invasive method to record faciolingual inclination and compare it with the CBCT derived angulations. So, a custom-made mounted angle protractor, a modification of Mestriner et al.[25] was used to measure the faciolingual inclination of each tooth on a patient cast. The values obtained were compared to those obtained from the CBCT software.

# ***Aim & Objectives***

## AIM

To compare the faciolingual inclination of maxillary teeth obtained using a customized Mounted Angle Protractor with a CBCT software

## OBJECTIVES

**1)** To estimate the faciolingual inclination of maxillary teeth using a Mounted Angle Protractor.

**2)** To compare the values obtained for the same patient with two CBCT values :

1. Crown inclination
2. Tooth inclination

**3)** To establish whether there are any significant changes in the values between the two methods.

# ***Background &***

# ***Review  of literature***

# BACKGROUND OF THE STUDY

Proper buccolingual inclination of both anterior and posterior teeth plays a crucial role in orthodontic treatment. This inclination ensures that teeth remain securely positioned within the dental arch, preventing unwanted shifting or instability. The alignment of teeth affects how they come together during biting and chewing. Proper buccolingual inclination contributes to a harmonious occlusion, where upper and lower teeth fit together optimally. Buccolingual inclination influences the visibility of teeth when smiling, ensuring an esthetically pleasing outcome. Balanced buccolingual inclination promotes efficient mastication and minimizes strain on the temporomandibular joint (TMJ) i.e. functional balance.

Orthodontic treatment aims to achieve these goals by considering tooth anatomy, bracket placement, and torque application. Well-aligned teeth enhance the smile's appearance.

Torque of the maxillary incisors is particularly critical in establishing an esthetic smile line, proper anterior guidance, and a solid Class I relationship, because under-torqued anterior teeth can preclude the retraction of the anterior maxillary dentition. Suboptimal torque of the incisors can deprive the dental arch of space,[67] while suboptimal torque of posterior teeth might not allow appropriate cusp-to-fossa relationships between the maxillary and mandibular teeth.[68] The knowledge about faciolingual inclination helps in treatment planning as well as in achieving individualized treatment objectives.

# REVIEW OF LITERATURE

**In 1972 Lawrence F. Andrews**,[2] based on his study on 120 casts of non-orthodontic patients with normal occlusion proposed the “six keys to normal occlusion.” He concluded that the absence of any one or more of the six results in occlusion that is proportionally less than normal and achieving the final desired occlusion is the purpose of attending to the six keys to normal occlusion.

**In 1972 Peck and peck** et al.[26] conducted a study to answer the question, “Do naturally well aligned mandibular incisors possess distinctive dimensional characteristics?” .The results of this study indicated that naturally well aligned mandibular incisors do possess distinctive dimensional characteristics, mesiodistally and faciolingually. When compared with mean crown dimensions from the control population group, lower incisors in perfect alignment are significantly smaller mesioditally and significantly larger faciolingually.

**In 1973 Carlsson and Rönnerman** et al.[34] designed a study to ascertain the range of variation and the effect of abrasion on crown- root angles of upper central incisors. The results clearly showed that the angles examined may differ widely from tooth to tooth. Further, the angles vary with the degree of abrasion because incision superius appears to shift facially with increasing abrasion. These observations should be borne in mind in the interpretation of the results of cephalometric analysis and biometric measurements including one or more of the angles examined.

**In 1976 Lear** et al.[84] described a method for analyzing the direction and extent of movement of root apices and midpoints of the incisal edges of maxillary central incisors. The system permitted detailed examination of the effectiveness of any orthodontic technique in relocating maxillary incisors and was particularly useful in determining the efficacy of "torquing" mechanisms.

**In 1978 Dellinger** et al.[27] elucidated torque from a statistical point of view. He measured third-order angulations from positioner setups and came to the same conclusion that in ideal occlusions facial tooth angulations show large standard deviations in the measurement

**In 1978 Morrow** et al.[28] studied angular changes of the facial surfaces in treated and untreated cases as well as extracted teeth and took measurements by means of an optical comparator and also came to the same conclusion that in ideal occlusions facial tooth angulations show large standard deviations in the measurements.

**In 1981 Perera** et al.[88] described a technique for relating dental structures to standardized lateral head radiographs in occlusion, through the use of oriented dental study casts. It was based on an occlusal plane which is common to both the radiograph and the dental study casts. An instrument has been described which enables the establishment of this defined plane and provides a means for obtaining arch measurements in that plane, supplying the third or lateral dimension to the two dimensions already available from radiograph.

**In 1982 Mayoral** et al.[14] evaluated "parallelism" and the incidence of root resorption in fifty-three extraction cases treated with light continuous wire therapy, following the principles of minimum force application, minimum tooth movement, avoiding the outward displacement of the roots from the apical bases, and a minimum time of active treatment. Differential tooth movement was performed and active displacement of the full complement of teeth was avoided when possible, according to the needs of the particular case. Panoramic radiographs were taken before and after active treatment and 1 year out of retention. The long axes of upper and lower canines and second premolars were traced and the angulation between them was measured to appraise root "parallelism." Only 1.8 percent root resorption was estimated for those teeth measured. It was concluded that the possible explanation for this low figure may be the mesiodistal movement of the teeth along the apical bone base, without deviations toward the labiobuccal or lingual sides.

**In 1984 Bryant** et al.[29] investigated the variability in tooth morphology of the maxillary central incisor using three anatomic features. The three features are the crown-root angulation in a labiolingual direction, the angle formed by a tangent to the middle of the labial surface of the crown and the long axis of the crown from a proximal view, and the lingual curvature of the crown from a proximal view. The results revealed a wide range of variation in the three features measured. The mean crown-root angle for Class II, Division 2 malocclusions differed significantly from that for Class II, Division 1 and Class III malocclusions. The other two features measured did not differ significantly among the four malocclusion groups.

**In 1985 Richmond** et al.[85] compared two- and three-dimensional incisor angulations are in 40 patients using lateral radiographs and direct dental cast measurement using the Reflex Metrograph coupled to a computer. The two-dimensional upper and lower incisor angulations to the occlusal plane were also compared by the two methods. It was found that: The two-dimensional radiographic and three-dimensional dental cast inter-incisor angulation showed a significant difference at a probability level 0.01 greater than p greater than 0.001. The two-dimensional radiographic and two-dimensional dental cast upper left and right incisor angulations to the functional occlusal plane showed a significant difference at a probability level of 0.01 greater than p greater than 0.001. The significant differences can be attributed to the measurement of the incisor crown angulation in the dental cast measurement and the incisor tip and apex assessment in the radiographic technique. The system of dental cast measurement arguably provides a more realistic and reliable assessment of incisal angles than conventional radiographic measurement techniques.

**In 1986 Vardimon** et al.[30] conducted a study to evaluate certain aspects of the third-order angulations in the normal human dentition. Torque data were recorded directly from casts by means of custom-made torque angle gauge, thus omitting the need to bisect the models. They concluded that the study is in close agreement with Andrews' mean torque values except those for the upper incisors and neither the setup procedure nor the morphometric parameters predict individual torque data.

**In 1987 Hussels and Nanda** et al.[57] evaluated the effects of angulation of incisors on dental arch length mathematically. The incisors are approximated mathematically to rectangular shapes, which enabled the authors to calculate the change in arch length when teeth were tipped and to describe graphically the effect of other influencing parameters. The authors demonstrated that the height and the width of a tooth crown can enhance or diminish the effect of angulation on arch length. In addition to angulation, dental arch length was also influenced by torque. A mathematic formula h was derived and the results were demonstrated numerically and graphically. The authors show that vertical positioning of the brackets plays an important role because torquing is a rotational movement around the center of the bracket slot. Hence, in calculating the effect of torque on dental arch length, one must consider different angles and axes.

**In 1988 Lucchesi** et al.[45] studied suitability of the panoramic radiograph for assessment of mesiodistal angulation of teeth in the buccal segments of the mandible. A mandibular phantom was used to investigate the suitability of the panoramic radiograph for assessment of the mesiodistal angulation of teeth in the buccal segments of the mandible. This Plexiglas model, housing steel pins at known angulation, was radiographed with both panoramic and plane-film techniques. Results indicated that plane-film techniques were more accurate than the panoramic technique for assessing mesiodistal root angulation.

**In 1989 Germane, Bentley, and Isaacson**[31] performed a study to measure the means and standard deviations present in (1) the facial contour present at the same location of the same type of tooth among different persons, (2) the faciolingual contour from occlusal/incisal to gingival areas among teeth of the same type, and (3) the angle formed by the long axis of the crown and the long axis of the root of teeth of the same type. When all of these factors are known, the ideal bracket slot position and the necessary variation in this position will be clear so that a straight arch wire can produce an ideal dental occlusion. They concluded that treatment must be tailored to the biologic variation presented by the individual patient.

**In 1990 Ross** et al.[32] evaluated faciolingual inclinations based on occlusal table inclinations relative to occlusal planes and correlated variations in faciolingual tooth inclinations with variations in vertical skeletal growth patterns. The study concluded that there was no differences in mean first molar faciolingual occlusal surface inclinations, relative to the posterior occlusal plane, between groups of patients with varying vertical facial proportions. However, the standard deviations were large. Mean maxillary incisor faciolingual inclinations relative to the OP differed between groups and increased as the MP-SN and OP-SN angles increased. The mean UI-SN angle did not differ between groups. Mean mandibular incisor faciolingual inclinations relative to the OP did not differ between groups; however, the mean L1-MP angle decreased as the MP-SN angle increased.

**In 1990 Ursi** et al.[46] assessed mesiodistal axial inclination through panoramic radiography and concluded that mesiodistal axial inclinations measured from orthopantomograms are as predictable as other standards of "normal" occlusions taken from two-dimensional representations of three-dimensional objects.

**In 1990 Germane** et al.[11] examined the contours of the facial surfaces of canines which contribute to their faciolingual inclination and determined tangent angles at four millimeters and five millimeters from the cusp tip of 100 maxillary and 70 mandibular canines. There was a significant difference between tangent angles at the same location on different canine teeth and also at different locations on the same canine tooth. Proximal collum angles were also measured in this study and there was a significant negative proximal collum angle in maxillary canines and a significant positive proximal collum angle in mandibular canines. It was concluded that the presence of these normal biologic variables will either enhance or minimize the torque supplied by preadjusted appliances, depending on a combination of prescription used and biologic variable present.

**In 1992 Balut** et al.[8] conducted a study to determine the accuracy of bracket placement with the direct bonded technique. Ten orthodontic faculty members bonded a preadjusted orthodontic appliance on models of five cases of malocclusion in a simulated clinical situation (mannequin). A total of 50 sets of models served as the population of the study. Photographs of the models were measured to determine vertical and angular discrepancies in position between adjacent bracket pairs from a constructed reference line. Variations are evaluated with respect to the classification of malocclusion, specific tooth type, and intra/inter operator differences. A mean of 0.34 mm for the vertical discrepancies and a mean of 5.54 degrees for the angular discrepancies are found in placement of the orthodontic brackets.

**In 1993 Kattner** et al.[7] compared Roth appliance and standard edgewise appliance treatment results using two indices. The first, the ideal tooth relationship index (ITRI), scored dental casts for the presence of ideal tooth contacts. The second judged post treatment dental casts on the basis of criteria established by Andrews in his "Six Keys to Normal Occlusion." The sample consisted of 120 orthodontically treated cases completed by two practitioners who have used both the Roth and standard edgewise appliances. The results of the Six Keys Analysis showed that the angulation and inclination of the maxillary posterior teeth were better with the Roth appliance. It was concluded that the success in achieving some components of the six keys did not translate into an increased percentage of ideal tooth contacts as measured by the ITRI. Despite using the Roth appliance, experienced clinicians still found it difficult to achieve all six keys to normal occlusion.

**In 1997 Ugur and Yukay**[33] conducted a study to determine the faciolingual inclinations of tooth crowns in normal occlusions and compared them with the torque values of patients treated with standard and pretorqued brackets. They concluded that considerable dispersion around the mean torque measurements in all teeth was found. In the normal occlusion group, negative crown torque was measured for upper incisors. Upper central incisors were found to be more upright than lateral incisors in all groups. There was no significant variation between the mean crown torque values of standard and Roth bracket groups. In both the standard and Roth bracket groups, lower first molars had a significant increase in lingual crown torque as compared with the normal occlusion group, which implies that lower molar torque should be handled carefully with the treatment with either bracket.

**In 1997 Jens Kragskov** et al.[69] compared the reliability of anatomic cephalometric points from conventional cephalograms and 3-D CT.They concluded that for standard lateral and frontal cephalometric points, there is no evidence that 3-D CT is more reliable than the conventional cephalometric methods in normal skull, and the benefit of 3-D CT cephalometric is indicated in the severe asymmetric craniofacial syndrome patients, as conventional cephalometrics is known to be inferior in these cases.

**In 1997 Miethke** et al.[9] evaluated third order tooth movements with straight wire appliances and the influence of vestibular tooth crown morphology in the vertical plane. The labial surface in the vertical plane was investigated in three sections. It was concluded that the changes of torque fluctuate on average between 1.3 degrees (mandibular front teeth) and 3.3 degrees (mandibular molars) for every 0.5 mm of vertical deviation.

**In 1998 S. Richmond** et al.[52] developed a valid, reliable, simple, inexpensive, and non-invasive method to record incisor inclination and compared it with the traditional lateral cephalometrically derived angulations and concluded that tooth inclination protractor (TIP) is a reliable and valid measure for assessing left and right maxillary and mandibular incisor crown inclination.

**In 1999 Miethke** et al.[10] the anatomic variation of all permanent teeth anterior to the second molar was described, and the impact of this variation to a vertical or horizontal displacement occurring in the 1st and 3rd order was assessed. It was concluded that the intra individual variation in tooth morphology is larger than the variation between the different types of preadjusted appliances. Thus, if the straight wire approach should be followed, the bracket would have to be custom made. All the calculations were made with the precondition that full size wires were used. If this is not the case, the discussion concerning individual prescription is only of limited importance.

**In 1999 E. A. O'Higgins** et al.[67] quantified the changes in maxillary arch length by altering the inclination of acrylic typodont incisor teeth and evaluated the influence of natural tooth size and shape on arch length. It was concluded that there is an increase in the dental arch length when the inclination of the acrylic maxillary incisors is increased in relation to the occlusal plane. This increase is not directly proportional to the degree of inclination. The space requirement in the maxillary labial segment differs, depending on which bracket prescription series is used. There is a greater space requirement when using the Roth series of brackets on upper anteriors in comparison with the Andrews' series on upper anteriors. The increased change in arch length with an increase in inclination was reproduced when using stone casts of natural incisors, duplicated from patients' models. There was a large variation in the space requirement when altering the inclination of the natural incisors due to their wide range in shape and size. All the arch length changes found in the natural teeth were greater than those found in the acrylic ones. Triangular-shaped natural incisors appeared to produce least change in the arch length for a given change in inclination, whereas those teeth that were parallel-sided produced a proportionately larger change. Barrel shaped teeth produced an intermediate amount of change. There is a great variation in the space requirement of patients' teeth as their inclination is altered. In order to quantify this space requirement, a change in the order of 1 mm can be expected when the inclination of the upper incisors is altered for each 5 degrees for an 'average' set of incisors. However, the exact amount will vary with the shape and size of the incisors. This allowance should be included in a space analysis when planning treatment for a patient

**In 2001 Ferrario** et al.[51] measured the 3-dimensional inclination of the FACCs relative to anatomical planes intrinsic to the dental cast and assessed the size of the clinical crowns in a normal, healthy population. Moreover, the effects of sex and age on the same variables were analyzed in healthy individuals with a sound complete permanent dentition. It was concluded that the frontal plane FACCs of most teeth converged toward the midline plane of symmetry. In contrast, the incisors diverged from the midline plane or were nearly vertical. Within each quadrant, the inclinations of the post incisor teeth progressively increased. In the sagittal plane, most teeth had a nearly vertical FACC. In the frontal plane, the canines, premolars, and molars were more inclined in adolescents than in adults. In the sagittal plane, a large within-group variability was observed. Clinical crown height was significantly larger in males than in females in all maxillary and mandibular canines, premolars, second molars, maxillary central incisors, and first molars. With age, some degree of dental eruption was found in maxillary and mandibular canines, maxillary second premolars, and molars. The age-related decrease in FACC inclination may be the effect of a progressive buccal and mesial drift.

**In 2002 Ghahferokhi** et al.[53] critically assessed the use of a disposable intraoral tooth protractor inclination (TIP) to record incisor crown inclination and compared this method with the use of an acrylic extra oral TIP and traditional lateral cephalograms.it was concluded that the disposable TIP is a reliable and valid tool for assessing left and right maxillary and mandibular incisor crown inclination. All 3 TIP techniques were reliable between examiners. There were statistically significant systematic differences between the TIP and the radiographic assessment. The following differences were found. The TIP tended to record maxillary incisor crown inclination an average of 14° less than upper incisor to maxillary plane. The TIP tended to record mandibular crown incisor inclination at a similar inclination as lower incisor to mandibular plane. The TIP recorded mandibular crown inclination 19° less compared with mandibular incisor to occlusal plane.

**In 2002 Mckee** et al.[37] compared the mesiodistal tooth angulations determined with a typodont/skull testing device with the images of mesiodistal tooth angulations from 4 contemporary panoramic units (OP 100, Cranex 3+, Orthophos, PM 2002 EC). Results revealed that most image angles from the 4 panoramic units were statistically significantly different from the true angle measurements. However, definite trends were noted among the panoramic units. For the maxillary teeth, the images projected the anterior roots more mesially and the posterior roots more distally, creating the appearance of exaggerated root divergence between the canine and the first premolar. For the mandibular teeth, the images projected almost all roots more mesially than they really were, with the canine and the first premolar the most severely affected. The largest angular difference for adjacent teeth occurred between the mandibular lateral incisor and the canine, with relative root parallelism projected as root convergence. It was concluded that the clinical assessment of mesiodistal tooth angulation with panoramic radiography should be approached with extreme caution and with an understanding of the inherent image distortions.

**In 2002 Bai** et al.[102] evaluate the effects of preadjusted bracket base shape, the morphology of tooth surface where bracket locates, and the suitability relevant to location of bracket on the preadjusted edgewise appliance technique. 1 vertical curve and 3 horizontal curves of the clinical crown surface of anterior teeth and bicuspid teeth were measured with the precise contour instrument on the 60 plaster models of the subjects who have normal occlusion in Sichuan province. It was found that variation of identical curve exists at the different heights between the teeth and between the individuals; the surface of the central zone of tooth-crown gradually protrudes from incisors to bicuspid teeth in the vertical direction, and the mesial contour of cuspid is more prominent than the distal in the horizontal direction. It was concluded that the 4 mm X 3 mm contour of the vestibular central zone of identical tooth-crown in different individuals is fairly stable; it is suitable for the location of preadjusted brackets. The vertical shifts of brackets could change the preadjusted torque value and the design of cuspid bracket should have the distinction between mesial and distal shape.

**In 2004 CA Lascala** et al.[35] performed a study to evaluate the accuracy of the linear measurements obtained in CBCT images using a NewTom CBCT machine. The results showed that the real measurements were always larger than those for the CBCT images, but these differences were only significant for measurements of the internal structures of the skull base. Concluded that although the CBCT image underestimates the real distances between skull sites, differences are only significant for the skull base and therefore it is reliable for linear evaluation measurements of other structures more closely associated with dentomaxillofacial imaging.

**In 2004 Janson** et al.[49] compared the buccolingual inclinations of the posterior teeth in subjects with a definite horizontal growth pattern (proportionally short lower anterior face height) with those in subjects with a definite vertical growth pattern (proportionally long lower anterior face height). They concluded that the maxillary posterior teeth in subjects with vertical growth patterns have a statistically significantly greater buccal inclination as compared with those with horizontal growth patterns. No statistically significant differences in the inclination of the mandibular posterior teeth could be found between the 2 groups.

**In 2004 Currim and Wadkar**[54] assessed the occlusal and coronal characteristics of untreated normals to determine whether first-, second-, or third-order bends should be added in the final finishing wire or to create a new bracket prescription to obtain better results when treating the Indian population. They concluded that tooth shape and position are constant for each tooth type. The data from this study were comparable with Andrews's findings. However, it would be safe to presume that all teeth except the maxillary second molars require alterations in the bracket base inclination value, and that the maxillary lateral incisor, canine, second premolar, and second molar, and the mandibular canine, require alterations in angulation values

**In 2004 Gregory L Adams** et al.[70] conducted a study to evaluate and compare a 3- D imaging system and traditional 2D cephalometry for accuracy in recording the physical measurements with a calibrated caliper on human dry skulls. They concluded that the 3D evaluation was much more precise, within approximately 1 mm of the gold standard and 4 to 5 times more accurate than the 2D approach.

**In 2004 Costalos** et al.[98] evaluated the ABO grading system for use on digital models and determined whether digital models can be used with reasonable accuracy and reliability for assessing patients' final occlusions. Plaster and digital (OrthoCAD, Cadent Inc, Carlstadt, NJ) posttreatment models of 24 patients were gathered from the postgraduate orthodontic clinic at Columbia University School of Dental and Oral Surgery. The plaster models were scored by using the ABO measuring gauge and the 7 criteria of the ABO grading system. It was concluded that alignment and buccolingual inclination should be reevaluated with both methods, and adequate calibration of the examiners is essential to achieve repeatability in both methods. Digital models might be acceptable for use in the ABO model examination.

**In 2005 N. Shah** et al.[50] designed and constructed a jig for measuring the inclination of the upper incisors to the maxillary plane and of the lower incisors to the mandibular plane. The results of the study showed that the inclinations of the upper and lower incisors arrived at after using the jig were accurate to within 10 degrees of the cephalometric value on 96 per cent of occasions and to within 6 degrees on 76 per cent of occasions.

**In 2006 M.A. Mestriner** et al.[48] evaluated the degree of b uccolingual inclination of mandibular tooth crowns relative to torque and drawn the following conclusions: 1 - Except for the mandibular incisors, which had a small difference in torque from each other (lingual root torque for central incisors and buccal root torque for lateral incisors), the other values were close to those found in the literature. 2 - Torque increased progressively in the three bonding heights for the mandibular central incisors, but the cervical height showed a more uniform pattern, with an average increase of nearly 5 degrees for adjacent teeth. 3 - The vertical shift of orthodontic brackets, from occlusal to cervical, affected normal torque values as follows: a) torque of mandibular incisors tended towards positive values (lingual root torque), as the bracket shifted from occlusal to cervical; b) torque of posterior teeth tended towards negative values (buccal root torque) at cervical heights compared to occlusal heights; c) the more cervical the position of the orthodontic appliance, the lesser the need for buccal root torque application. 4 - Average variations between the bonding extremes, i.e., occlusal and cervical, were: a) central and lateral incisors: approximately 2 degrees; b) canines: approximately 3 degrees; c) premolars and molars: approximately 8 degrees.

**In 2006 Scarfe et al.**[71] "Clinical Applications of Cone-BeamComputed Tomography in Dental Practice", stated that ComputedTomography is of 2 types - fan beam and cone beam. The advantages of cone beam are image accuracy, rapid scan time, dose reduction, display modes unique to maxillofacial imaging and reduced image artefact. Cone Beam Computed Tomography (CBCT) provides spatial relations of bony anatomic elements and extended pathologic knowledge of various maxillofacial structures. CBCT imaging provides clinicians with sub-millimetre spatial resolution images of high diagnostic quality with relatively short scanning times (10–70 seconds) and a reported radiation dose equivalent to that needed for 4 to 15 panoramic radiographs.

**In 2007 Mazyar Moshiri** et al.[72] compared the accuracy of linear measurements made on photostimulable phosphor cephalograms with 3 methods for stimulating lateral cephalograms with Cone Beam Computed Tomography. They concluded that CBCT derived two dimensional LCs proved to be more accurate than LCs for most linear measurements calculated in the sagittal plane. No advantage was found over single frame basis images in using ray-sum generated cephalograms from the CBCT volumetric data set.

**In 2007 Okunami** et al.[99] conducted a study were to determine whether the American Board of Orthodontics objective grading system (ABO OGS) can be assessed accurately from digital dental casts and whether there are statistical differences between digital and plaster dental casts in scoring the ABO OGS. Thirty post treatment plaster dental casts were selected and scanned by OrthoCAD (Cadent, Carlstadt, NJ) to produce 30 corresponding digital dental casts. The plaster and digital casts were compared by using the criteria of the ABO OGS. Because the data were ordinal, a non parametic statistical analysis was used. It was concluded that the current OrthoCAD program (version 2.2) was not adequate for scoring all parameters as required by the ABO OGS.

**In 2008 Lagravère** et al.[36] conducted a study to verify the accuracy of landmark coordinates and linear and angular measurements of standard 9-in and 12-in images obtained from the NewTom 3G (Aperio Services, Verona, Italy) compared with a coordinate measuring machine (CMM) (MicroVal, Brown and Sharpe, North Kingston, RI), the gold standard. They concluded that NewTom 9-in and 12-in 3D images have a 1-to-1 ratio with real coordinates and with the linear and angular distances obtained by the CMM.

**In 2008 Garcia-Figueroa** et al.[38] evaluated the effect of buccolingual root angulation on the perception of root parallelism in panoramic images and concluded that when the buccolingual angulation changes, the largest angular differences between adjacent teeth occurred in the canine-premolar area. These discrepancies were larger for the maxillary arch than for the mandibular arch. Buccolingual angulation changes in the incisor area do not seem to affect the expression of root parallelism in panoramic images. The clinical assessment of root parallelism with panoramic x-rays should consider the buccolingual orientation effects on the angular distortions in the image, especially in premolar extraction sites.

**In 2008 Owens and Johal.**[39] compared the difference between the actual mesiodistal root angulation and the mesiodistal root angulation as measured on the panoramic radiograph and concluded that the panoramic radiograph provided a poor representation of true mesiodistal root angulations, and this was more notable in the lower arch. Clinicians must exercise caution in relation to panoramic radiographic findings when basing their clinical decisions as to whether teeth require further adjustments in angulation.

**In 2008 Danielle R. Periago** et al.[73] conducted a study to compare accuracy of linear measurements made on Cone Beam Computed Tomographic (CBCT) derived 3-dimensional (3D) surface rendered volumetric images to direct measurements made on human skulls. They concluded that while many linear measurements between cephalometric landmarks on 3D volumetric surface renderings obtained using Dolphin 3D software generated from CBCT datasets may be statistically significantly different from anatomic dimensions, most can be considered to be sufficiently clinically accurate for craniofacial analyses.

**In 2008 Silva** et al.[94] compared the radiation doses for conventional panoramic and cephalometric imaging with the doses for 2 different CBCT units and a multi-slice CT unit in orthodontic practice and stated that the effective dose was lower for panoramic and lateral cephalometric device (10.4_Sv), and highest for multi-slice CT (429.7 _Sv). Therefore from a radiation-protection point of view, the routine use of CBCT is not recommended in orthodontic procedures. However when 3D imaging is required in orthodontic practice, CBCT should be preferred over multi-slice CT.

**In 2009 M. Knösel** et al.[44] conducted a study to evaluate the relationship of third order measurements on dental casts with those on lateral radiographs, and to identify those incisor features on radiographs which can best explain third order measurements on dental casts and concluded that assessing third order angles on dental casts is a sufficiently reliable method and one that is appropriate for routine orthodontic practice. The transferability of the data obtained to commonly used archwire and bracket prescriptions is a further advantage. Third order angles can also be derived with sufficient accuracy from lateral radiographs.

**In 2009 Al-Abdwani, Moles, Noar** et al.[47] evaluated changes in the cephalometric position of points A and B due to an incisal inclination change caused by orthodontic treatment and concluded that incisal tooth proclination or retroclination because of orthodontic treatment will result in a change in the position of point A and a possible change in point B in the horizontal plane. There is a direct association that can be used to relate one to another. Although the results were statistically significant, the magnitude of the change has been found to be clinically irrelevant. There was no evidence that changes in incisal inclination affect the position of points A and B in the vertical plane.

**In 2009 Mauricio Berco** et al.[74] conducted a study to determine the accuracy and reliability of 3-dimensional craniofacial measurements obtained from Cone-Beam Computed Tomography (CBCT) scans of a dry human skull. They concluded that CBCT allows for clinically accurate and reliable 3-dimensional linear measurements of the craniofacial complex. Moreover, skull orientation during CBCT scanning does not affect the accuracy or the reliability of these measurements.

**In 2009 De Vos** et al.[97] reviewed the benefits of Cone Beam Computed Tomography systems over medical CT for orthodontic treatment and planning. CBCT is used in orthodontics for numerous clinical applications particularly for its low cost, easy accessibility and low radiation compared with multi-slice Computerized Tomography. The limits allied with CBCT scanners are increased scatter radiation, limited dynamic range of X-ray area detectors, and beam hardening artifact.

**In 2010 Van Elslande** et al.[43] assessed the accuracy of a CBCT pan-like image in the projection of the mesiodistal tooth angulations on an anatomic typodont skull testing device. Gold standard angular measurements of each tooth were calculated by using a coordinate measuring machine (CMM). They concluded that the mesiodistal angular projection of teeth on the CBCT pan-like image is closer to the true mesiodistal angulation. If the practitioner is well acquainted with how the information from the CBCT is processed to create the pan-like image, it can be a useful tool for evaluating mesiodistal root angulations.

**In 2010 Ribeiro** et al.[96] analyzed the rapid maxillary expansion using CBCT and reported that the lateral relocation of the maxilla and increased basal bone can be accurately observed which confirms the marked morphological changes that occur in the upper arch and nasomaxillary structure. They concluded that CBCT is a revolutionary diagnostic method in dentistry as it provides high dimensional accuracy of the facial structures and areliable method for quantifying the manner of the maxillary halves, dental tipping, bone formation of the suture in the three planes of space, as well as alveolar bone resorption and other cost of palatal expansion.

**In 2010 Fukagawa** et al.[103] evaluated tooth inclination in the elderly from the orthodontic point of view. The dental casts of twenty elderly persons with many remaining teeth were digitized with a 3D laser scanner (VMS-100F,UNISN INC, Osaka, Japan) for reconstruction into 3-D images. Inclination of each tooth was then measured with an analytical software (SURFLACER, UNISN INC and IMAGEWARE 12, UGS PLM Solutions, MO, USA). The occlusal plane formed by the incisal edge of the central incisor and distal buccal cusp tip of the first molar on either side was used as a reference plane to measure tooth inclination, and the complementary angle as tooth inclination was measured. They concluded that there was no statistical difference between men and women, except for the maxillary lateral incisors. Tooth inclination showed a progressive decrease from anterior to posterior. The decrease in the mandibular teeth was more regular than that of the maxillary teeth.

**In 2010 Brezniak** et al.[104] examined the correlation between the inclinations of maxillary incisors measured on a cephalometric lateral head film and the light reflection zone appearing on the buccal surface of the teeth on anterior intraoral photographs. The light reflection zone on the tooth surface as it appears on intraoral photographs-incisal, middle, or gingival-correlated with statistical significance to the angular inclination of the teeth-proclination, normal inclination, and retroclination, respectively as determined by means of cephalometric analysis. They concluded that incisor inclination can be determined by not only cephalometric analysis but also the light reflection zone viewed on the buccal surface of intraoral photographs. This method might be used as a new screening tool and further as an additional clinical tool for assessing treatment plans in orthodontics and other fields of dentistry.

**In 2010 Kodaka** et al.[100] conducted a study to develop a measurement procedure of inclination. The data that was measured by laser scanner, was compared with the data measured by manual procedure in the same sample, and also with the data with previous reports to evaluate the laser scanner system. The mean value measured by laser and that measured by manual procedure in the same sample did not detect significant differences. It was concluded that laser could objectively measure inclinations with less prejudice and or human error of examiner. This procedure would be useful in research and in the clinic

**In 2010 Sjögren** et al.[105] investigated the reproducibility of angular measurements made on virtual digital models, the O3DM system and agreement between a traditional technique. It was concluded that the conventional method showed better reproducibility for angular variables. The differences between the two methods in reproducibility of linear variables did not show any clear pattern except for overbite, which showed less variability when measured with the 03DM system. Reproducibility was considered clinically acceptable for both methods. Systematic errors indicated that the two methods should not be used inter changeably.

**In 2011 W. Schlicher** et al.[42] quatified the consistency and precision of landmark identification in three dimensional Cone Beam Computed Tomography scans and concluded that there was no significant improvement in the overall consistency or precision in landmark identification as the examiners quantified 19 patients. Sella was the landmark with the best consistency at 0.50 ± 0.23 mm. Left maxillary cant/palatal recess was the landmark with poorest consistency at 2.70 ± 1.51 mm. Landmarks on curves continue to have more errors than those with clear anatomic delineations. While overall consistency is important in understanding the general error in a landmark's identification error, an understanding of the individual axis consistency is essential for appreciating how error can affect craniofacial measurements in three dimensions. Utilization of landmarks should consider the distribution of error in each dimension so that the most accurate measurements can be made.

**In 2011 Cao** et al.[56] evaluated the effect of maxillary incisor labiolingual inclination and AP position on smiling profile esthetics in young adult females. It was concluded that a maxillary incisor that is upright or in slight lingual inclination is preferable, despite the AP position of the maxillary incisors. Labial inclination of the upper incisors could easily ruin a pleasing smiling appearance. Maxillary incisor protrusion is preferable to retruded incisors.

**In 2011 Bruno Fraza Gribel** et al.[75] conducted a study to compare the accuracy of craniometric measurements made on lateral cephalograms and on Cone Beam Computed Tomography (CBCT) images. They concluded that CBCT craniometric measurements are accurate to a subvoxel size and potentially can be used as a quantitative orthodontic diagnostic tool.[4]

**In 2011 Shewinvanakitkul** et al.[90] described a practical and reliable method to measure buccolingual inclination of mandibular canines and first molars using Cone Beam Computed Tomography and a commercially available DICOM software.

**In 2012 Tong** et al.[40] measured mesiodistal angulation and faciolingual inclination of each whole tooth with volumetric Cone-Beam Computed Tomography images and developed the custom USC Root Vector Analysis Program to measure the mesiodistal angulation and the faciolingual inclination of each whole tooth from a typodont.

**In 2012 Tong** et al.[41] measured mesiodistal angulation and faciolingual inclination of each whole tooth in 3- dimensional space in patients with near-normal occlusion and concluded that using the custom University of Southern California root vector analysis program in Dolphin 3D software can be used in patients with near-normal occlusion

**In 2013 Shu, Han, Wang, Xu, Ai, Wang, Wu, Bai** et al.[55] compared the arch width, alveolar width, and buccolingual inclination of maxillary and mandibular posterior teeth between Class II division 1 malocclusion and Class I occlusion. Buccolingual inclination of maxillary and mandibular premolars and first molars were measured with a modified Universal Bevel Protractor. They concluded that the maxillary posterior teeth are significantly more lingually tilted in Class II division 1 malocclusion compared with in Class I occlusion. The first mandibular premolars are less lingually tilted in Class II division 1 malocclusion than in Class 1 occlusion, whereas there is no difference in buccolingual inclination of mandibular second premolars and first molars between the two groups. The arch width of posterior teeth is not different between Class II division 1 malocclusion and Class I occlusion. The buccolingual inclination plays a more important role in transverse discrepancy of Class II division 1 malocclusion than arch width.

**In 2013 Ludlow** et al.[76] calculated the effective doses in various combinations of field of view size and field location comparing child and adultanthropomorphic phantoms. Scan protocols used were high resolution (360 degrees rotation, 600 image frames, 120 kV[p], 5 mA, 7.4 seconds), standard (360 degrees, 300 frames, 120 kV[p], 5 mA, 3.7 seconds), QuickScan (180degrees, 160 frames, 120 kV[p], 5 mA, 2 seconds), and QuickScan+ (180degrees, 160 frames, 90 kV[p], 3 mA, 2 seconds). QuickScan+ effective doses were comparable with conventional panoramic examinations. Significant dose reductions were accompanied by significant reductions in image quality.

**In 2013 Huanca Ghislanzoni** et al.[93] developed and validated a novel analysis protocol to measure linear and angular measurements of tip and torque of each tooth in the dental arches of virtual study models. The study demonstrated that the digital analysis had adequate reproducibility, providing additional information and more accurate intra-arch measurements for clinical diagnosis and dentofacial research.

**In 2014 Nouri** et al.[58] measured the inclination of teeth on dental casts by a manual technique with the tooth inclination protractor (TIP; MBI, Newport, United Kingdom) and a newly designed 3-dimensional (3D) software program. The correlation of the 2 techniques was evaluated, and the reliability of each technique was assessed separately. They concluded that the TIP and the 3D software showed a high correlation for measurement of the inclinations of maxillary and mandibular teeth relative to the occlusal plane. Also, the reproducibility of the measurements in each method was high.

**In 2014 Verma** et al.[59] evaluated angulation and inclination of teeth from the study models of individuals with normal occlusion and compared expression of torque by three different bracket systems. A self-developed instrument (torque angle gauge) was used for the measurement. They concluded that there was a highly significant correlation of teeth angulation and inclination in the maxillary and mandibular arch. Though the error in expression of torque was not significant, it showed a large range, indicating the need to vary the position of brackets in different bracket systems for achieving optimum torque.

**In 2015 Xu** et al.[60] investigated the effect of buccolingual inclinations of the maxillary canines and premolars on the perceived attractiveness of the smile when viewed from the frontal perspective using a 3-dimensional digital dental model. The smile images were assessed by 2 panels, orthodontists and lay people. They concluded that it could be aesthetically satisfying to position the teeth within the ranges of 0˚ to -7˚ of inclination for the canines and -3˚ to -11˚ of inclination for the premolars, as assessed by the orthodontists, or of 3˚ to -10˚ of inclination for the canines and 5˚ to -11˚ of inclination for the premolars, as assessed by the lay persons. Clinicians could exercise flexibility within this range, when compromising tooth positions for transverse jaw discrepancies.

**In 2015 Zarif Najafi** et al.[61] evaluated incisor inclination in smiling profiles with respect to mandibular position to determine the preferred maxillary incisor inclination in the smile profile with regard to different mandibular positions. They concluded that it is crucial to establish a normal incisor inclination, especially in patients with a mandibular deficiency or excess. An excessive maxillary incisor lingual inclination should be avoided regardless of the mandibular position.

**In 2015 Lombardo** et al.[92] analysed the tip, torque and in-out values of two groups of different racial and ethnic background. Rhinoceros™ 3D Modelling Software was used to identify anatomical reference points, planes and axes and to make the appropriate measurements. They concluded that race and ethnicity have a strong influence on values of tip, torque and in-out. This is translated as a more positive tip in Caucasian subjects and a more positive torque in those of African descent (greater proclination of the incisors).

**In 2017 Jain** et al.[62] investigated and quantified the influence of angulation and inclination of maxillary incisors on the effective arch perimeter. The study revealed that increase in maxillary incisor crown angulation by 1˚ results in consumption of approximately 0.012 mm of arch perimeter. Similarly, there is a consumption of 0.021 mm of arch perimeter with each degree increase in lingual crown inclination.

**In 2017 Yun-Hoa Jung** et al.[77] measured the buccal bone thickness and angulation of the maxillary incisors and to analyze the correlation between these parameters and the root position in the alveolar bone using Cone-Beam Computed Tomography (CBCT) and noticed most of the maxillary incisor roots were positioned close to the buccal cortical plate and had a thin buccal bone wall. Significant relationships were observed between the root position in the alveolar bone, the angulation of the tooth in the alveolar bone, and buccal bone thickness. CBCT analyses of the buccal bone and sagittal root position are recommended for the selection of the appropriate treatment approach

**In 2017 Michelle Sendyk** et al.[78] conducted a study to find out the correlation between buccolingual tooth inclination and alveolar bone thickness in subjects with class III dentofacial deformities and concluded that the alveolar bone thickness was thick in the palatal surfaces of the maxillary central incisors and thinner in the labial surface of the mandibular central incisors which states that a significant correlation exists between inclination and thickness of teeth

**In 2019 Nouri** et al.[91] measured the change in inclination of teeth after the periods of 2 and 4 years in adolescents with normal occlusion using three-dimensional (3D) software. The inclination of teeth was determined by 3D measurements using OrthoAid software. After scanning the casts via stereophotogrammetric scanner, the mean and standard deviation of inclination of teeth were calculated at three time points. They concluded that sex significantly affected the changes in the inclination of teeth throughout the period of study. The variation of changes in torque was considerable, and no consistent pattern was defined.

**In 2019 Gull** et al.[95] measured buccolingual inclination of maxillary and mandibular first molars in untreated sample of pre-orthodontic patients using volumetric images obtained from Cone-Beam Computed Tomography (CBCT) scans which show the dentofacial structures in a 1:1 ratio, and distortions, if any, are clinically insignificant. The average inclination of maxillary molar was +4.98º ± 4.26º. The average inclination of mandibular molar was -13.10º ± 6.10º. There was no significant difference between the right and left values. They concluded that Maxillary and mandibular molars have a natural curvature of their inclinations where the maxillary molars have a slight buccal inclination and mandibular molars have a slight lingual inclination.

**In 2020 Golshah** et al.[65] assess the buccolingual inclination of canine and first and second molar teeth and the curve of Wilson in different sagittal skeletal patterns in untreated adults using Cone-Beam Computed Tomography (CBCT). The sagittal skeletal pattern was determined using the ANB angle and Wits appraisal. Inclination angles were measured by NNT Viewer and Mimics software. The curve of Wilson was measured by connecting the tips of mesiobuccal and mesiolingual cusps of maxillary first and second molars along the buccal groove and measuring the formed angle. It was concluded that in different sagittal skeletal patterns, a compensatory relationship exists between the opposing teeth, which, along with the standards of crowns, can be used to determine the appropriate position of teeth in dental arch.

**In 2021 Bukhary** et al.[63] determined the tip and torque values of the teeth of Saudi adults with normal occlusion to develop orthodontic bracket prescription. Also compared the results with published data of varied geographical distribution. The torque and tip of teeth were measured using a torque angulation device. They concluded that statistically significant differences were found between the combined Saudi data when compared to North American, Italian, African, Japanese, and Indian data. Also inferred, that racial differences should be considered when presenting bracket prescriptions.

**In 2021 Sara M Al-Mashhadany** et al.[66] conducted a study to find out whether anterior teeth angulation and inclination have a relationship with the maxillary teeth and dental arch dimensions. Study indicated that it is important to consider different factors such as angulation and inclination in addition to overbite, overjet, tooth size ratio, and arch dimensions in developing the diagnosis and treatment planning to get final optimal occlusion of the finished cases.

**In 2023 Sivanandam** et al.[64] evaluated and compared the variations in torque expression in maxillary incisor and canine using different bracket prescriptions placed at different crown levels by finite element method. It was concluded that the magnitude of displacement of root apex was significantly influenced by bracket prescription and bracket position. Also, the stress developed in the bracket was influenced by bracket prescription and position, while the variation in crown morphology in the incisor and canine played a significant role in the eventual strain developed in the PDL after torque application.

# ***Relevance of the study***

# RELEVANCE OF THE STUDY

The evaluation of faciolingual inclination is an important part of orthodontic treatment planning, as well as assessing treatment progress and determining treatment outcome. Incisor inclination has traditionally been assessed by lateral cephalometric radiographic analysis. However, deriving axial inclinations of incisors from lateral cephalometric radiograph is prone to relatively large digitizing errors.[79-81]

Dental casts have been useful in assessing tooth and arch parameters, arch asymmetry, and arch length. Few studies have used dental casts to assess incisor inclination. Carey[82] used an incisor angulator, and Lundstrom[83] used a slide gauge. Three-dimensional assessment techniques have also been employed.[84-86] Techniques have been described relating study casts to lateral cephalometric radiographs.[87, 88] Richmond et al.[89] described the use of an acrylic extraoral device to assess incisor inclination. However, none of these techniques is routinely used because they may be unreliable, costly, and time consuming, or require experienced personnel to record and process the data.

This suggests the requirement of a predictable setting and a device to measure the same. Comparison of the values obtained with CBCT will help in establishing the reliability of the data.

# ***Materials & methods***

**STUDY DESIGN**

This study was designed as a Cross-sectional study.

**STUDY SETTING**

This study was conducted on patients reporting to Department of Orthodontics & Dentofacial Orthopedics, St.Gregorios Dental College, Chelad, Kothamangalam

**SAMPLING**

- Data was analysed using the statistical package SPSS 22.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p<0.05$.
- Descriptive statistics was performed to assess the mean and standard deviation of the respective groups.
- Normality of the data was assessed using Shapiro Wilkinson test.
- Inferential statistics to find out the difference between and within the groups was done using Independent t test /Man Whitney U test.
- The total sample size was estimated at 29 with a power of 80%. The sample size was rounded of to 30.

**Sample size**

- $n = 2 \times \frac{(\frac{Z\alpha}{2} + Z\beta)^2}{(d1-d2)^2} \times SD^2$
- Z α/2 =Type 1 error (5%) =1.96
- Z β = Type1 error (20%) =0.84(Power of the study 80%)
- SD =Standard deviation = 1.5 (From literature)
- d1-d2 =minimally detectable difference=1.1
- n= $\underline{(1.96+0.84)^2 \times 1.5^2}$
- $1.1^2$
- n =2 × $\underline{7.84\times}$ 2.25 = 29.4≈ 30samples
- 1.21
- FINAL SAMPLE SIZE= 30

**INCLUSION CRITERIA**

- Patients requiring CBCT evaluation.
- Patients with no history of orthodontic treatment.
- No history of trauma to the upper anterior teeth.
- Age – 18- 25 years.
- Rotation less than 15˚, limited to 3 teeth.
- Dental crossbite limited to 1 tooth and less than 2 mm.
- No deciduous maxillary teeth present.
- No missing or extracted permanent teeth in maxillary arch.
- No restoration of the dental cusps of measured teeth.
- Clearly visible land marks on CBCT scan (cusp tips and root apices).
- No evident facial or skeletal asymmetry.

**EXCLUSION CRITERIA**

- A significant medical or dental history (e.g., use of bisphosphonates or bone altering medications, or diseases).
- Poor image quality.
- Craniofacial abnormality including cleft lip.
- Patient with history of trauma induced fracture of jaw bones.
- Multiple tooth impactions.
- Malformed tooth.

## MATERIALS

- CBCT Hardware: Planmeca Promax 3D plus CBCT Machine (Fig 6)
- CBCT Software: Planmeca Romexis Viewer version 5.3.3.5 (Fig 7)
- CBCT images of 30 patients before orthodontic correction
- Laptop supporting windows: Acer Aspire 3 with intel core i5 processer
- Mounted angle protractor: Jaibros rectangular degree protractor angle finder
- Alginate impression material: Impreceed alginate impression material from GC Corporation, Tokyo, Japan
- Type III Orthodontic stone: Kalabhai Orthokal orthodontic stone class III from Kalabhai Karson Pvt. Ltd.
- Stone casts of the same 30 subjects before orthodontic correction.

## METHODOLOGY

The current study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, St.Gregorios Dental College, Chelad, Kerala. 30 Patients between age group of 18-25 years, who needed CBCT evaluation for definitive diagnosis were selected for the study. The selection of the patients were based on the above mentioned inclusion and exclusion criteria described for the study. The consent for treatment were taken from all the 30 patients during their time of treatment which was used in the study. The study protocol was approved by the Institutional Ethical Committee (IEC no: SGDC/152/2022/4344).

Alginate impressions of all the thirty patients, who satisfies the selection criteria, were made for the maxillary arch, poured with Orthokal and the study models were prepared. Functional Occlusal Plane (FOP) was formed by the three most occlusally located cusps of maxillary first molars and premolars as described by Ross et al.[32]The maxillary cast base was trimmed parallel to the FOP. The facial axis of clinical crown (FACC) and its midpoint , the facial axis (FA) point, were marked on each crown of maxillary teeth of one quadrant, as described by Andrews.[3] The faciolingual inclination of each tooth crown were measured as the faciolingual angle between teeth and the OP using a mounted angle protractor from the cast. The protractor readout arm was adjusted parallel and tangent to the FACC at the facial axis point using the set screw and the inclination of the crown was read on the protractor's scale. Each inclination was measured three times by the same observer, and the average value was adopted for statistical analysis.

**The Mounted Angle Protractor**

The Mounted Angle Protractor (Fig 1) was developed to record the inclination of the maxillary teeth on dental casts. The device consists of a platform with a rotating table for placing the cast. The platform was perforated on one end to receive a vertical lead screw attachment. A horizontal arm with rectangular degree protractor angle finder was attached to the lead screw. The height of the horizontal arm was adjusted using the lead screw which in turn adjusted the height of the readout arm of the protractor to lie against the labial surface of maxillary tooth. The reading on the protractor reflected the inclination of the crown to their respective occlusal planes.

**Faciolingual inclination recording procedure using Mounted Angle Protractor**

For recording the faciolingual inclination (Fig 2) the dental cast was placed on the rotating table on the platform of the device. While measuring the faciolingual inclination of each tooth the rotating table ensured easy adjustment. The readout arm of the protractor was then adjusted using the lead screw so that it was placed against the labial surface of each tooth at their maximum bulbosity. The inclination was read off the protractor.

Figure 1: Mounted Angle Protractor

Figure 2: Mounted Angle Protractor measuring crown inclination

**CBCT imaging**

CBCT was taken using Planmeca Promax 3D plus with exposure parameters of 90kvp, 8mA, scan time (0.04sec). Faciolingual inclination of each tooth as well as tooth crown was assessed from the sagittal and coronal sections of the image obtained with the help of angle tool in the software. The faciolingual inclination with respect to a perpendicular to the occlusal plane and long axis of each crown as well as whole tooth was measured using the software. Outlines were traced manually in each section in each slice. The inclination was determined in individual sections by Romexis software. Each measurement was done by the same observer on three separate days and the mean value was taken as the final inclination. The values obtained from the two methods was compared.

Pre-treatment CBCT images of patients were taken for the study. All the CBCT files were imported into Planmeca Romexis Viewer version 5.3.3.5 imaging software (Fig 7 and 8) to obtain the angular measurements needed for the study. CBCT images were evaluated to measure faciolingual inclination of each tooth as well as tooth crown. The faciolingual inclination sagittal and coronal section images of the anterior teeth and posterior teeth respectively were obtained from the software. Using the angle tool in the software the angular measurements were obtained.

<u>Calculation of faciolingual inclination of maxillary anteriors</u>: Midsagittal plane was adjusted to patient's skeletal midline, and the tooth to be measured was located in the axial view, at the point at which the root was longest in the sagittal view. In the sagittal view, the line representing the long axis of the tooth was positioned. The angle between this long axis and a perpendicular to the occlusal plane was measured using the angle tool in the software and it was recorded as tooth inclination (Fig 4 and 5). In the same sagittal view, long axis of crown was also positioned, and crown inclination (Fig 3 and 5) was measured.

<u>Calculation of faciolingual inclination of maxillary posteriors</u>: Midsagittal plane was adjusted to patient's skeletal midline, and the tooth to be measured was located in the axial view, at the point at which the root is longest in the coronal view. In the coronal view, the line representing the long axis of the tooth was positioned. The angle between this long axis and a perpendicular to the occlusal plane was measured using the angle tool in the software and it was recorded as tooth inclination (Fig 4 and 5). In the same coronal view, long axis of crown was also positioned and crown inclination (Fig 3 and 5) was measured.

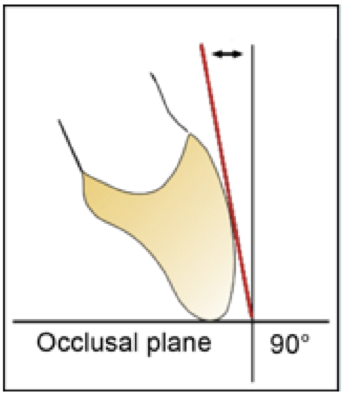


Figure 3: Crown inclination

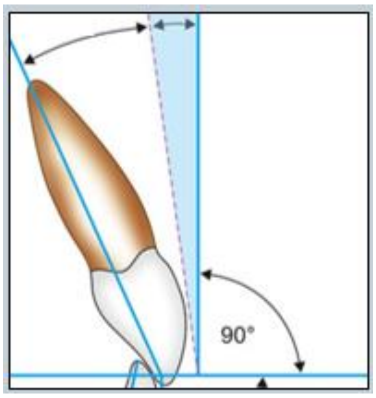


Figure 4: Tooth inclination

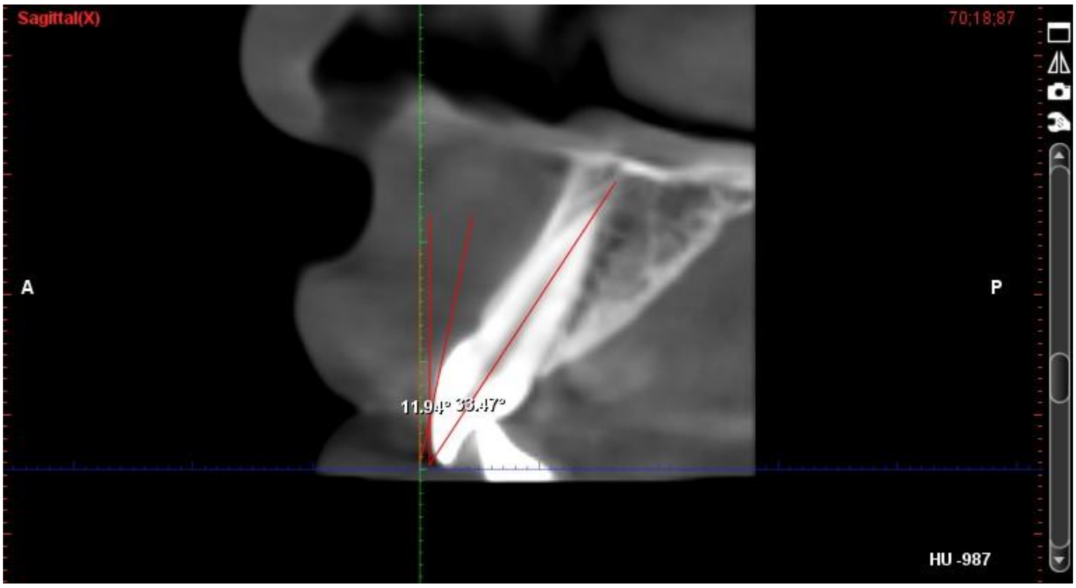



Figure 5: CBCT image showing faciolingual inclination measurements of crown and tooth.

Figure 6: Planmeca Promax 3D Plus CBCT Machine


Figure 7: Planmeca Romexis Viewer Version 5.3.3.5

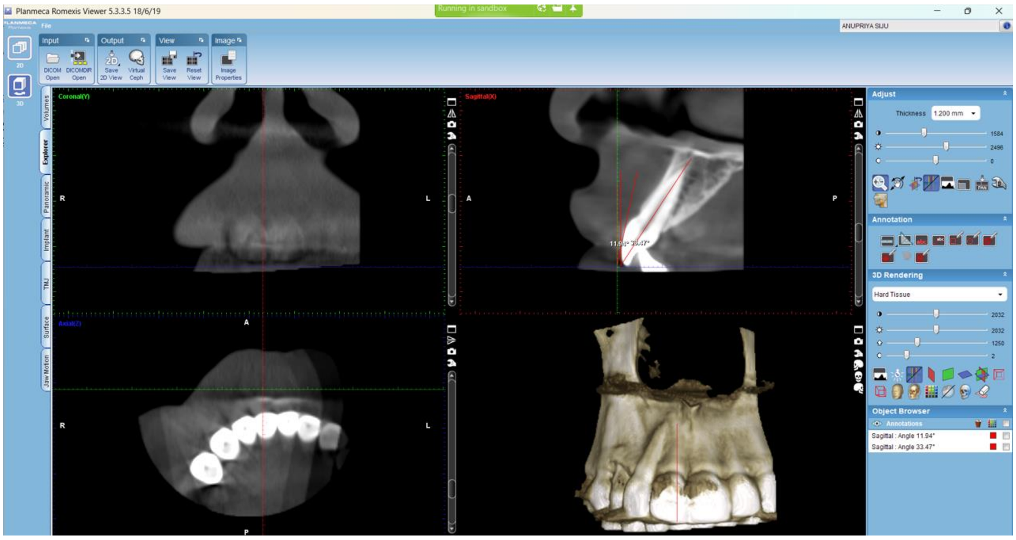


Figure 8: Planmeca Romexis Viewer Version 5.3.3.5 - software

# ***Results***

**STATISTICAL ANALYSIS**

Data was analyzed using the statistical package SPSS 26.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p<0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed using Shapiro Wilkinson test. Inferential statistics to find out the difference between the groups was done using Mann Whitney U test. Spearman Rank Correlation test was done to check the correlation analysis.

**TABLE 1-Measurement of 'Crown Inclination'- Central Incisor**

| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **9.36$^0$** | **9.92$^0$** |
| **SD** | **2.18$^0$** | **2.34$^0$** |

**TABLE 2-Measurement of 'Crown Inclination'- Lateral Incisor**

| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **7.4$^0$** | **7.49$^0$** |
| **SD** | **1.99$^0$** | **2.35$^0$** |

**TABLE 3-MEasurement of 'Crown Inclination'- Canine**

| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **10.76$^0$** | **10.94$^0$** |
| **SD** | **1.97$^0$** | **1.97$^0$** |

**TABLE 4-Comparison of 'Crown Inclination'-First Premolar**

| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **10.8$^0$** | **11.16$^0$** |
| **SD** | **2.02$^0$** | **2.18$^0$** |

**TABLE 5-Comparison of 'Crown Inclination'- Second Premolar**

| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **10.86$^0$** | **11.50$^0$** |
| **SD** | **2.02$^0$** | **2.25$^0$** |

## FACIOLINGUAL INCLINATION

### MAXILLARY CENTRAL INCISORS

The faciolingual inclination of the maxillary central incisor crown measured using the protractor and CBCT is depicted in table 6. The Protractor measurement was 9.36º ± 2.18º and CBCT measurement was 9.92º ± 2.34º.

**TABLE 6-Comparison of 'Crown Inclination'- Central Incisor**

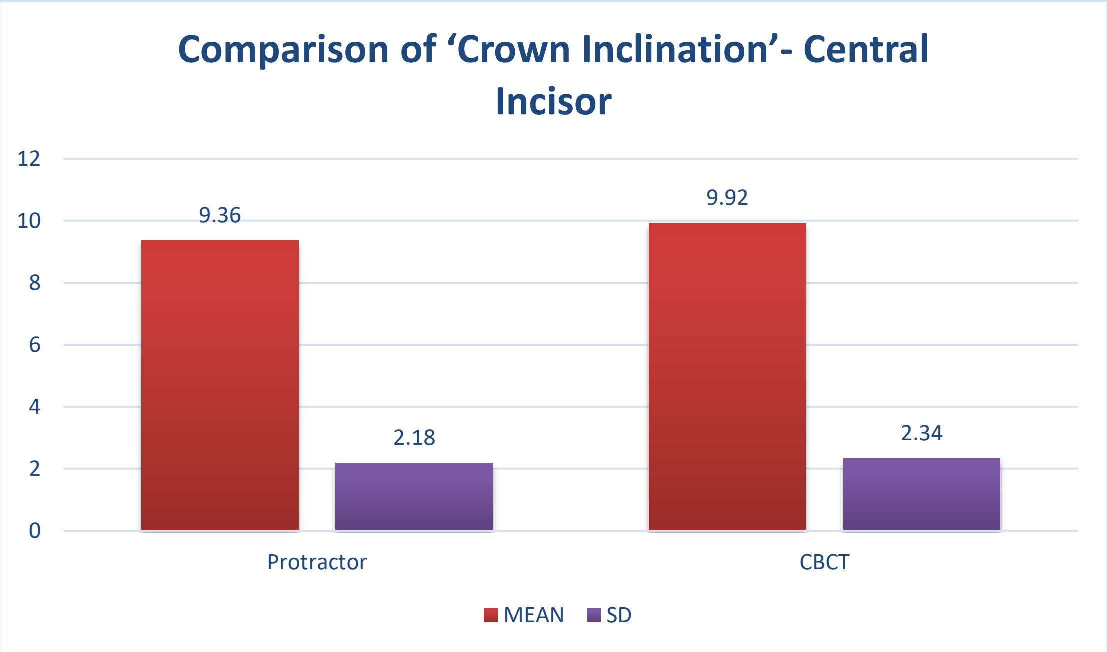
| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **9.36º** | **9.92º** |
| **SD** | **2.18º** | **2.34º** |
| **Z VALUE** | **0.75** | |
| **P VALUE** | **0.45** | |

***P<0.05 is statistically significant (Shapiro Wilkinson test, P<0.05)**

**INFERENCE:**

Shapiro wilkinson test for normality reported significant difference(P<0.05), hence Non Parametric tests are used for the analysis. Regarding 'Crown Inclination – Central Incisor' between group analysis by Mann Whitney U Test did not report statistically significant difference (P>0.05). The CBCT group reported marginally higher mean value compared to Protractor mean ( 9.92º > 9.36º).

**Graph 1**



## MAXILLARY LATRAL INCISORS

The faciolingual inclination of the maxillary lateral incisor crown measured using the protractor and CBCT is depicted in table 7. The Protractor measurement was 7.40º ± 1.99º and CBCT measurement was 7.49º ± 2.35º.

**TABLE 7-Comparison of 'Crown Inclination'- Lateral Incisor**

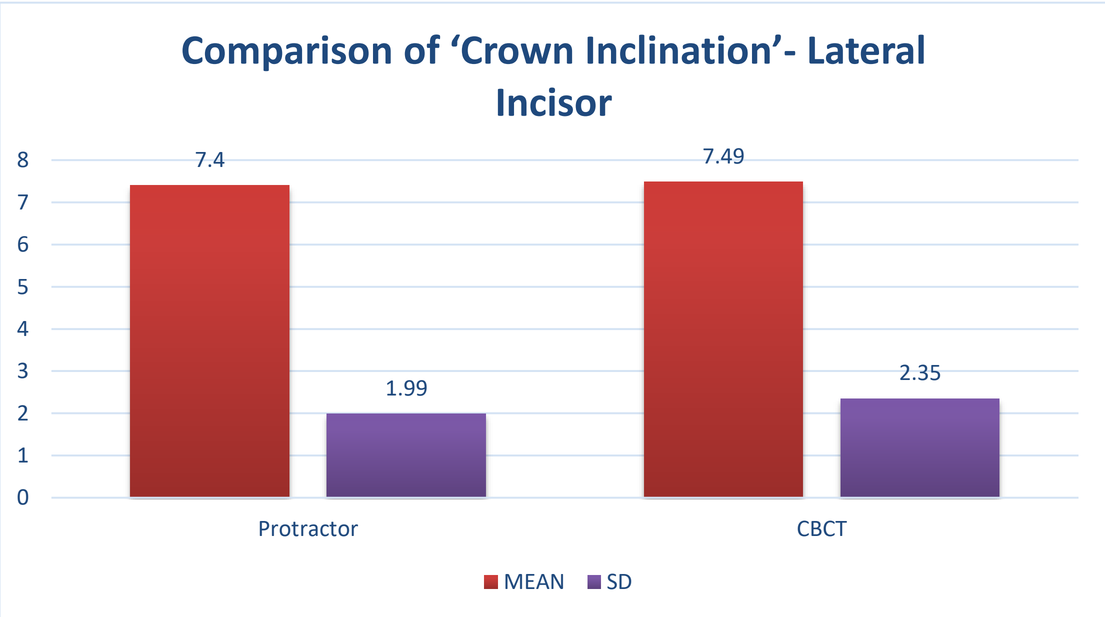
| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **7.4º** | **7.49º** |
| **SD** | **1.99º** | **2.35º** |
| **T VALUE** | **0.16** | |
| **P VALUE** | **0.87** | |

***P<0.05 is statistically significant (Shapiro Wilkinson test, P<0.05)**

**INFERENCE:**

Shapiro wilkinson test for normality reported significant difference(P<0.05), hence Non Parametric tests are used for the analysis. Regarding 'Crown Inclination – Lateral Incisor' between group analysis by Mann Whitney U Test did not report statistically significant difference (P>0.05). The CBCT group reported marginally higher mean value compared to Protractor mean ( 7.49º > 7.4º).

**Graph: 2**



## MAXILLARY CANINE

The faciolingual inclination of the maxillary canine crown measured using the protractor and CBCT is depicted in table 8. The Protractor measurement was 10.76° ± 1.97° and CBCT measurement was 10.94° ± 1.97°.

**TABLE 8-Comparison of 'Crown Inclination'- Canine**

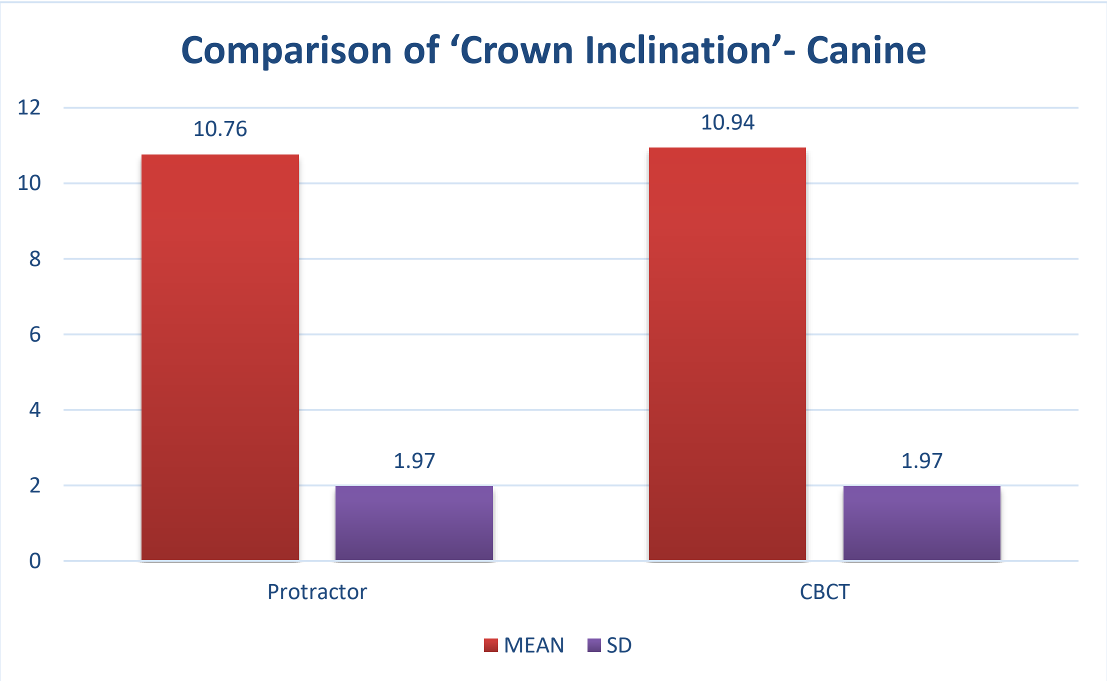
| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **10.76°** | **10.94°** |
| **SD** | **1.97°** | **1.97°** |
| **T VALUE** | **0.35** | |
| **P VALUE** | **0.72** | |

***P<0.05 is statistically significant (Shapiro Wilkinson test, P<0.05)**

## INFERENCE:

Shapiro wilkinson test for normality reported significant difference(P<0.05), hence Non Parametric tests are used for the analysis. Regarding 'Crown Inclination – Canine' between group analysis by Mann Whitney U Test did not report statistically significant difference (P>0.05). The CBCT group reported marginally higher mean value compared to Protractor mean ( 10.94° > 10.76°).

***Graph: 3***



## MAXILLARY FIRST PREMOLAR

The faciolingual inclination of the maxillary 1st premolar crown measured using the protractor and CBCT is depicted in table 9. The Protractor measurement was $10.80^{\circ} \pm 2.02^{\circ}$ and CBCT measurement was $11.16^{\circ} \pm 2.18^{\circ}$.

**TABLE 9-Comparison of 'Crown Inclination'-First Premolar**

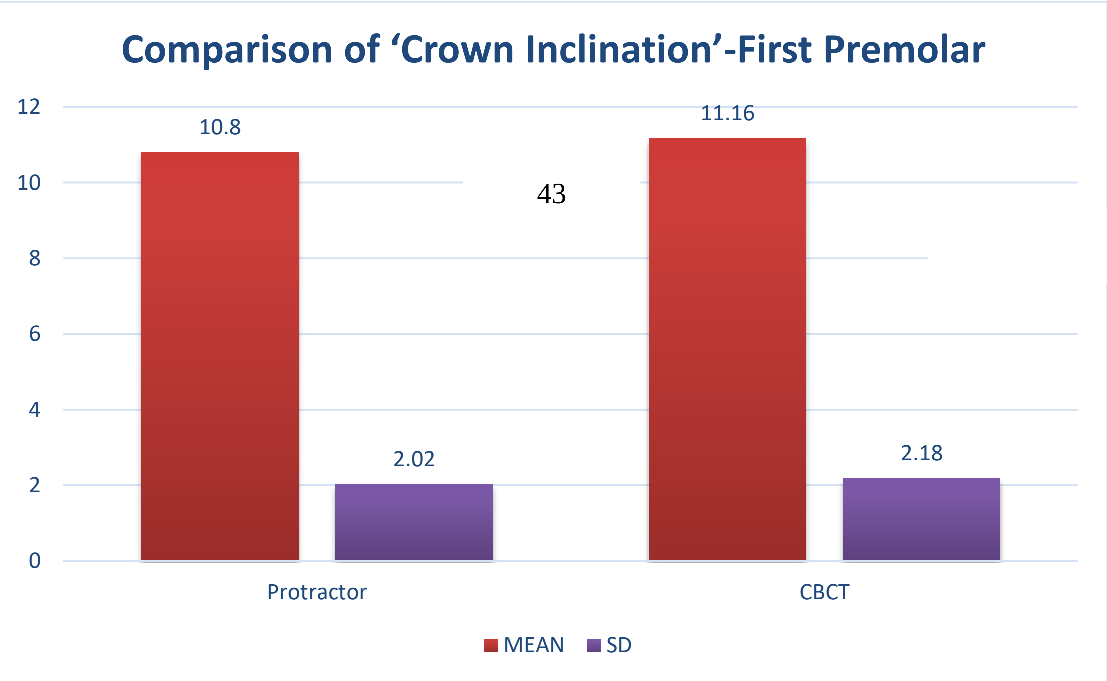
| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **10.8º** | **11.16º** |
| **SD** | **2.02º** | **2.18º** |
| **T VALUE** | **0.66** | |
| **P VALUE** | **0.50** | |

***P<0.05 is statistically significant (Shapiro Wilkinson test, P<0.05)**

## INFERENCE:

Shapiro wilkinson test for normality reported significant difference(P<0.05), hence Non Parametric tests are used for the analysis. Regarding 'Crown Inclination – 1st Premolar', between group analysis by Mann Whitney U Test did not report statistically significant difference (P>0.05). The CBCT group reported marginally higher mean value compared to Protractor mean ( $11.16^{\circ} > 10.8^{\circ}$).

**Graph: 4**



## MAXILLARY SECOND PREMOLAR

The faciolingual inclination of the maxillary 2nd premolar crown measured using the protractor and CBCT is depicted in table 10. The Protractor measurement was 10.86º ± 2.02º and CBCT measurement was 11.50º ± 2.25º.

**TABLE 10-Comparison of 'Crown Inclination'- Second Premolar**

| | Protractor | CBCT |
|---|---|---|
| **MEAN** | **10.86º** | **11.50º** |
| **SD** | **2.02º** | **2.25º** |
| **T VALUE** | **1.15** | |
| **P VALUE** | **0.25** | |

***P<0.05 is statistically significant (Shapiro Wilkinson test, P<0.05)**

## INFERENCE:

Shapiro wilkinson test for normality reported significant difference(P<0.05), hence Non Parametric tests are used for the analysis. Regarding 'Crown Inclination – 2nd Premolar, between group analysis by Mann Whitney U Test did not report statistically significant difference (P>0.05). The CBCT group reported marginally higher mean value compared to Protractor mean ( 11.50º> 10.86º).

**Graph: 5**

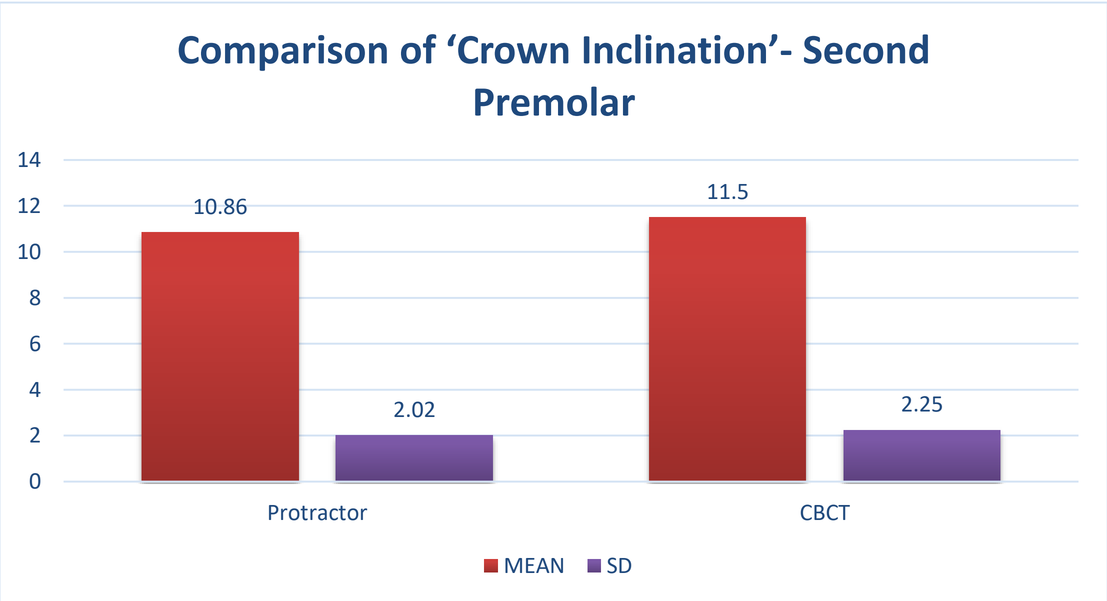


**TABLE 11- Correlation Analysis by Spearman Rank Correlation test**

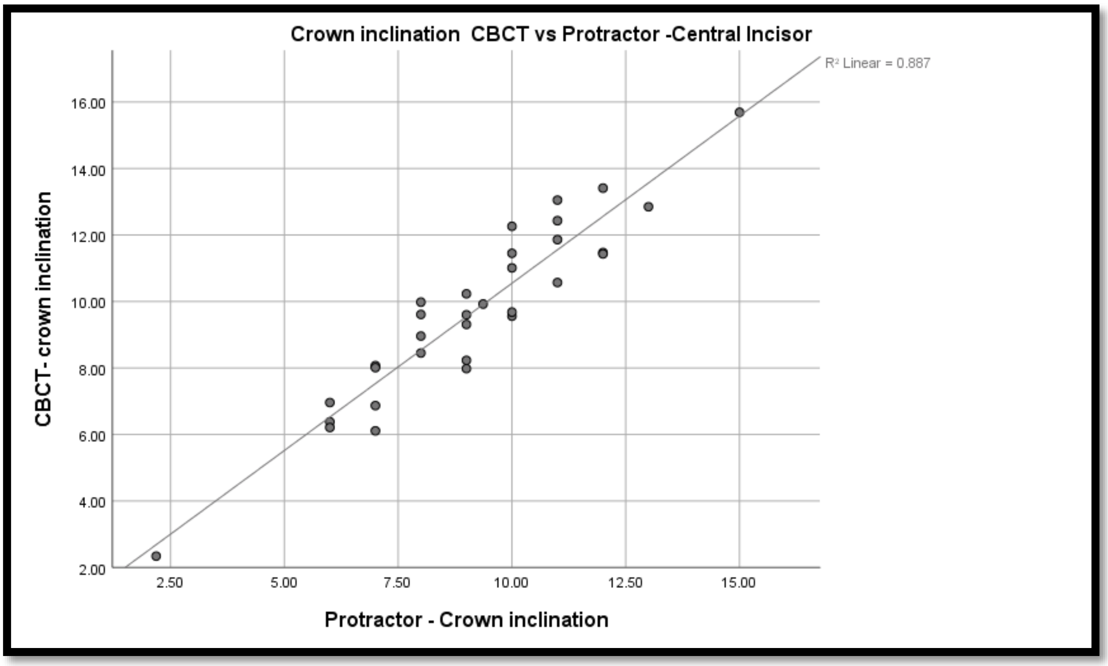
| | Correlation | P value |
|---|---|---|
| **CI** | **0.92** | **0.0001*** |
| **LI** | **0.90** | **0.0001*** |
| **C** | **0.92** | **0.0001*** |
| **1 PM** | **0.91** | **0.0001*** |
| **2 PM** | **0.93** | **0.0001*** |

**P<0.05 is statistically significant**

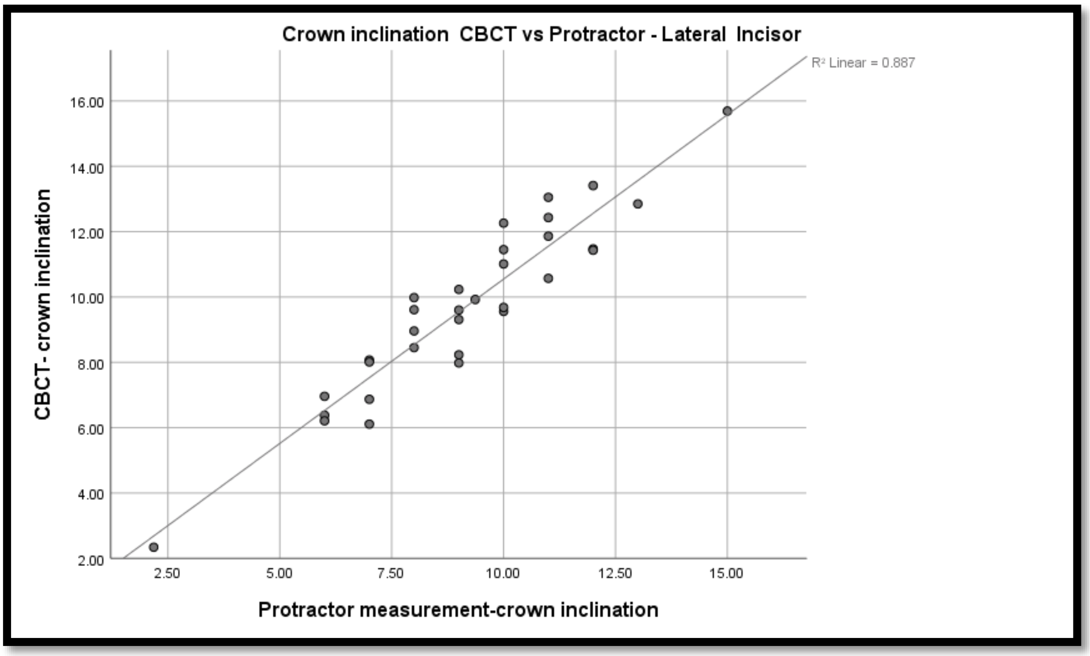
## INFERENCE:

Spearman Rank Correlation analysis reported excellent positive correlation between crown inclination measure by CBCT & Mounted Angle Protractor (P<0.05) regarding all 5 teeth (CI, LI, C, 1st PM & 2nd PM).

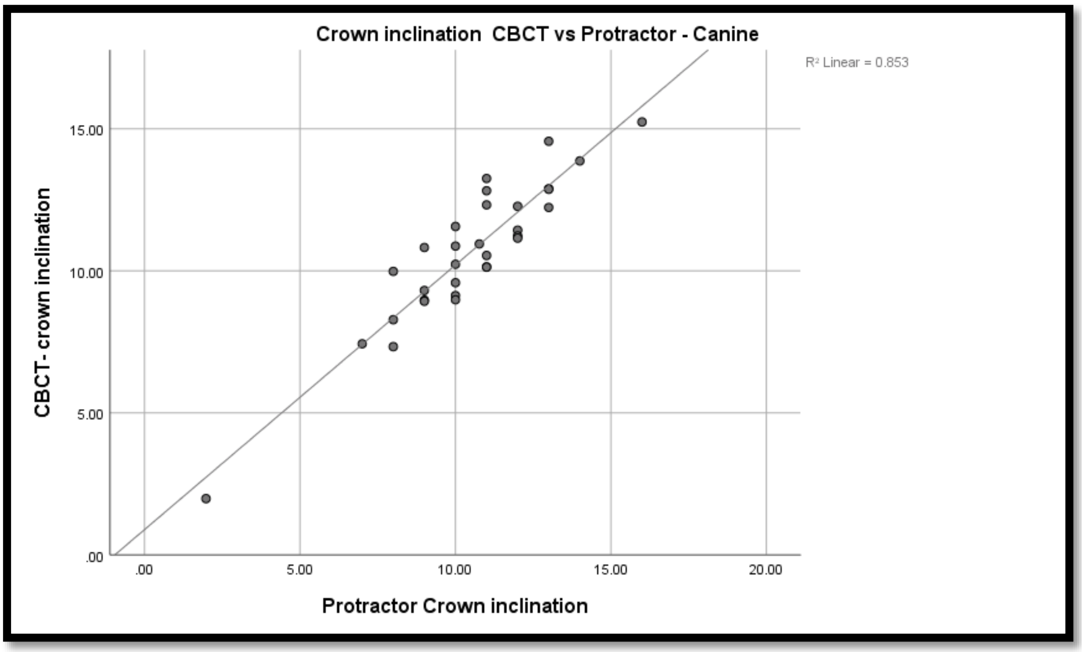
**Graph: 6**



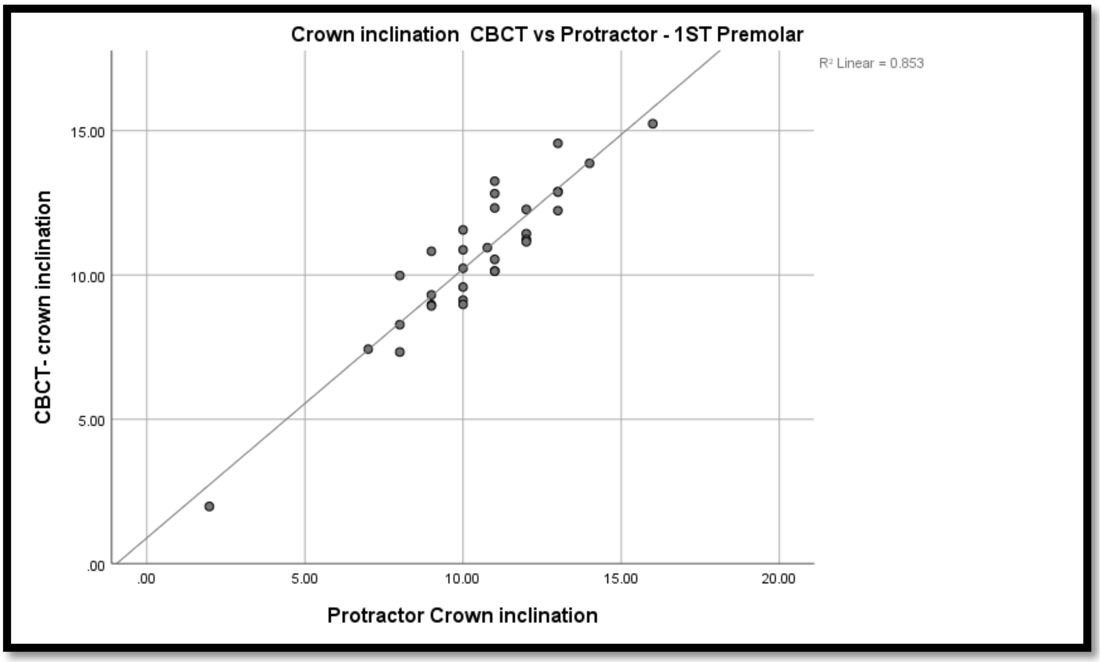
**Graph: 7**



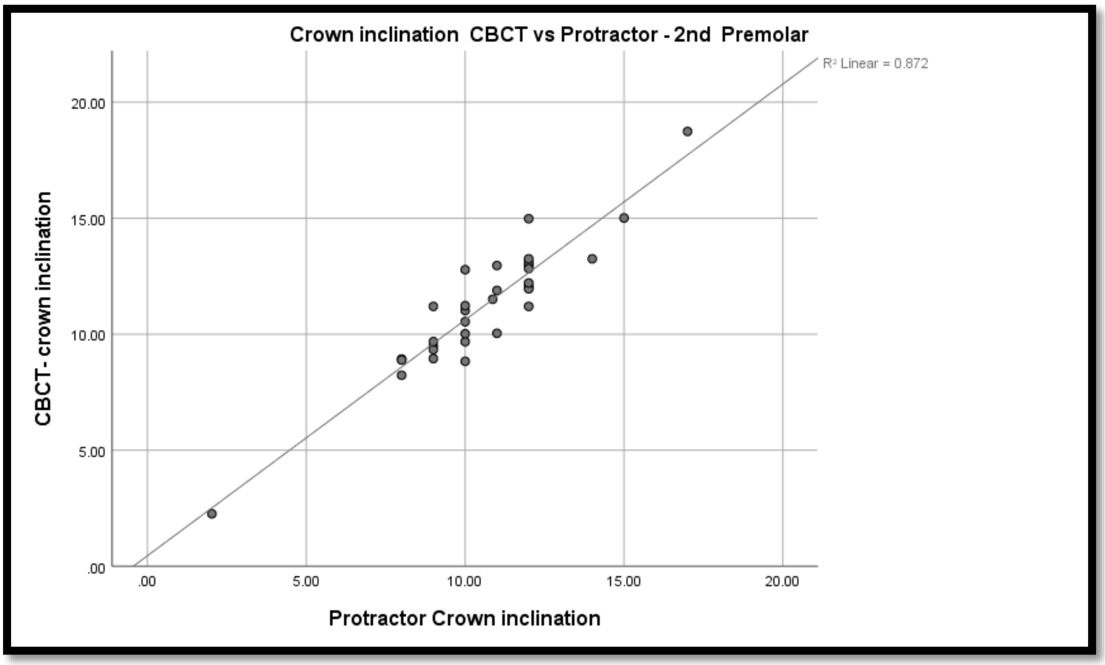

**Graph: 8**



**Graph: 9**



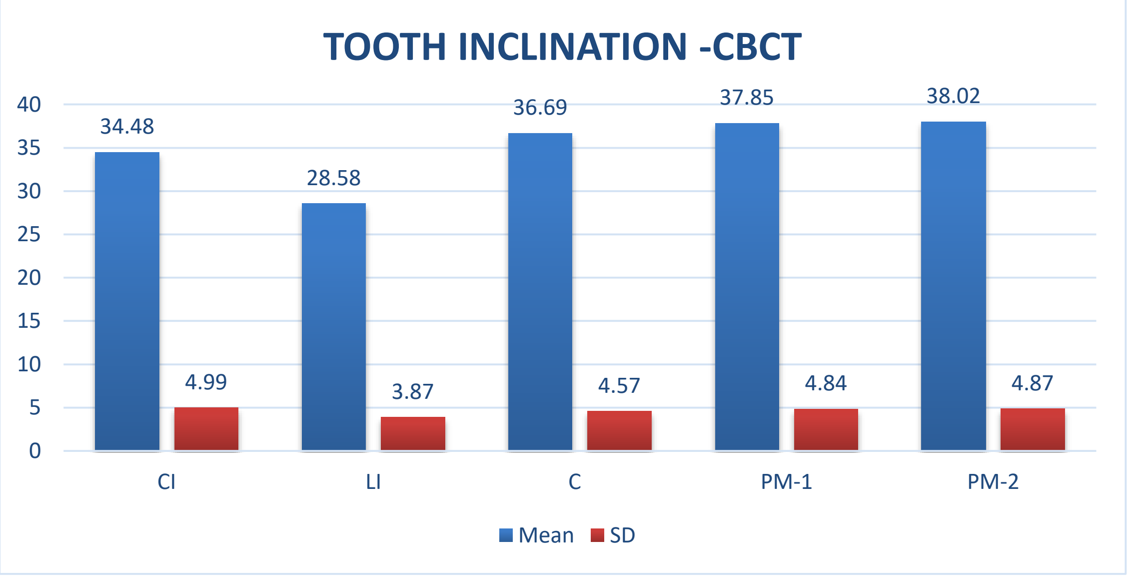

**Graph: 10**



<u>**TABLE 12- Mean Value of Tooth inclination- CBCT**</u>

| | Mean | SD |
|---|---|---|
| **CI** | **34.48$^{0}$** | **4.99$^{0}$** |
| **LI** | **28.58$^{0}$** | **3.87$^{0}$** |
| **C** | **36.69$^{0}$** | **4.57$^{0}$** |
| **1 PM** | **37.85$^{0}$** | **4.84$^{0}$** |
| **2 PM** | **38.02$^{0}$** | **4.87$^{0}$** |

**Graph: 11**



# RESULTS

The present study evaluated the faciolingual inclination of maxillary teeth using a customized Mounted Angle Protractor and compared the crown inclination with the CBCT measurement. 30 patients between age group of 18-25 years, who needed CBCT evaluation for definitive diagnosis were selected for the study. The selected patients had no history of orthodontic treatment. The data required for the study was collected from the CBCT records in the Department of Orthodontics and Dentofacial Orthopaedics, St.Gregorious Dental College, Kothamangalam. Stone casts of the same patients requiring CBCT evaluation for definitive diagnosis were also used for the study.

Pretreatment CBCT images were incorporated into Planmeca Romexis Viewer version 5.1.0.4 imaging software in which faciolingual inclination of teeth were measured. For the evaluation of faciolingual inclination of maxillary teeth, the long axis of each whole tooth as well as long axis of the crown was drawn in the imaging software. Using the angle tool in the software, the angle between the long axis of the whole tooth and a line perpendicular to the occlusal plane was measured. The angle between the long axis of crown and the perpendicular to the occlusal plane was also measured using the angle tool. The faciolingual inclination of maxillary teeth were measured using the customized Mounted Angle Protractor and the values obtained were compared with the CBCT values.

The following results were obtained from the study:

**The faciolingual inclination of the maxillary central incisor crown**: The protractor measurement was 9.36º ± 2.18º and CBCT measurement was 9.92º ± 2.34º. Excellent positive correlation (r = 0.887) between crown inclination measure by CBCT and Mounted Angle Protractor for maxillary central incisor. The difference between two values did not report statistically significant difference (P>0.05).

**The faciolingual inclination of the maxillary lateral incisor crown**: The protractor measurement was 7.40º ± 1.99º and CBCT measurement was 7.49º ± 2.35º. Excellent positive correlation (r = 0.887) between crown inclination measure by CBCT and

Mounted Angle Protractor for maxillary lateral incisor. The difference between two values did not report statistically significant difference ($P>0.05$).

**The faciolingual inclination of the maxillary canine crown**: The protractor measurement was 10.76º ± 1.97º and CBCT measurement was 10.94º ± 1.97º. Excellent positive correlation ($r = 0.853$) between crown inclination measure by CBCT and Mounted Angle Protractor for maxillary canine. The difference between two values did not report statistically significant difference ($P>0.05$).

**The faciolingual inclination of the maxillary 1st premolar crown**: The protractor measurement was 10.80º ± 2.02º and CBCT measurement was 11.16º ± 2.18º. Excellent positive correlation ($r = 0.853$) between crown inclination measure by CBCT and Mounted Angle Protractor for maxillary 1st premolar. The difference between two values did not report statistically significant difference ($P>0.05$).

**The faciolingual inclination of the maxillary 2nd premolar crown**: The protractor measurement was 10.86º ± 2.02º and CBCT measurement was 11.50º ± 2.25º. Excellent positive correlation ($r = 0.872$) between crown inclination measure by CBCT and Mounted Angle Protractor for maxillary 1st premolar. The difference between two values did not report statistically significant difference ($P>0.05$).

# ***Discussion***

The present study was designed to determine the faciolingual crown inclination and to compare this data with the CBCT derived values.

The major challenge had been the development of an adequate methodology that would be capable of yielding reliable values with direct clinical application. The reference plane FOP as described by Ross et al.[32] is found to be stable after the eruption of a complete permanent dentition,[49] easy to detect, intrinsic to the cast itself eliminating any need for adjunctive data.[50,51]As orthodontists work mainly with dental crowns, the facial surface of the clinical crowns are best suited for assessing the inclination of all teeth completely erupted into the oral cavity due to easy visualization both clinically and on dental casts.[52]

Determination of buccolingual inclinations of several teeth has been widely investigated.[49, 53, 11] There were two concerns, firstly, how to quantitatively represent inclination of an irregularly convex surface and then, how to enhance reproducibility of the angular measurements made. Some answers were proposed: buccolingual inclination could be represented by a tangent vertical to this surface. For this tangent to represent values with clinical application, the chosen tangency point was the one considered as representative of the bracket location.[48] The vestibular central zone of identical tooth-crown in different individuals is fairly stable and is suitable for the location of preadjusted brackets.[102] In the present study, this was determined by the protractor pointer. Secondly, literature provided two solutions for the determination of the second reference line, namely a line perpendicular to the occlusal plane [19] or a line representing the long axis of either the tooth or the clinical crown.[50] But the latter did not present a direct clinical application because it only denoted the dental anatomy and failed to consider the relationship of teeth with the face or with the occlusion. Hence the reference line that denoted the vertical tangent to the facial surface at FA point and the line perpendicular to the FOP were chosen.

In the literature, various techniques have been used for the measurement of axial inclinations of teeth, and variable landmarks have been used.[52, 53, 55, 58] Traditionally, lateral cephalograms were used to measure the inclination of the incisors.[58] This technique provided the crown-root inclination relative to a horizontal reference plane (palatal, occlusal, or mandibular). However, the mistakes in registering the landmarks to assess the inclination of each tooth, or using the occlusal plane as the reference, and the ionizing beam radiation are among the short comings of this technique.[91] In dental cast-based methods, some of these drawbacks have been obviated. Andrews[5] tried to determine the tooth crown inclination, considering the facial axis of the clinical crown and the occlusal plane that passes through the anterior and posterior teeth. He used a glass sheet, a conveyor, and a compass for this purpose and aimed to determine the norm of tooth crown inclinations. However, his technique was both time-consuming and relatively difficult.

The Mounted Angle Protractor developed in this study is similar to Tooth Inclination Protractor [TIP], which was first introduced for the measurement of the inclination of incisors on a dental cast.[52]Previous studies have demonstrated that the TIP is a simple, inexpensive, and reliable tool for the assessment of tooth inclination.[52, 53] Such advantages were determining factors for its use for measuring tooth inclinations on dental casts in a study by Nouri et al.[58] However, it has some inherent deficiencies regarding the validity of the measurements, especially in the case of an inordinate occlusal plane (e.g., deep curve of Spee, severe curve of Wilson, canted occlusal plane, malposed teeth, or open-bite malocclusion).[52, 53] We used casts of near normal occlusions because our main objective in this study was to compare the 2 devices for their axial inclination measurements capabilities. Richmond et al.[52] reported correlations of 0.77 and 0.59 for the inclinations of the maxillary and mandibular incisors, respectively, between their invented technique and lateral cephalometry. Also, they showed that the TIP consistently underestimated the maxillary incisor inclination by 10.46 compared with lateral cephalometry, but it overestimated the inclination of mandibular incisors. In a similar study, Ghahferokhi et al.[53] demonstrated that the TIP underestimated the inclination of incisor crowns by an average of 14 relative to the maxillary plane on lateral cephalometry. However, the TIP calculated the inclination of mandibular incisor crowns relative to the mandibular plane, similar to the value in lateral cephalometry. In the study by Nouri et al.[58], the agreement index values between the 2 methods were 0.657 and 0.806, respectively, for measurement of the inclinations of the maxillary and mandibular incisors. Moreover, the 3D software overestimated the inclinations of maxillary and mandibular teeth by 2.875 and 2.925, respectively.[58] Although in this study the inclination of the incisors in lateral cephalometry was not measured, considering the differences between the study results and those of Richmond et al.[52], we can assume that the 3D software generally tends to report the inclination of maxillary incisors closer and that of mandibular incisors farther than the values measured on lateral cephalometry compared with the TIP. Meanwhile, when interpreting these results, it should be taken into account that the horizontal reference plane used in the 3D method was slightly different from the one used in the TIP.[9]

Although variety of inclination determining gauges were designed for both clinical and laboratory purposes, some calculated inclination angles using Pythagoras theorem,[50] while others had hand-held components[5,52] which posed risk to data reliability and reproducibility. To overcome such practical difficulties in angulation measurements, a custom-made Mounted Angle Protractor was constructed to enable standardization of both horizontal reference plane (parallel to FOP) and the vertical reference plane (perpendicular to FOP). This method was less time-consuming and more accurate.

As compared to similar researches[5, 54] in the past, a notable feature of this study was the methodology adopted for measurements which enhanced the validity and reproducibility of data. The device could be used for determining the angular changes of any tooth in either arch on any dental casts. This study determined the faciolingual inclination of teeth using Mounted Angle Protractor and compared the values with CBCT derived values.

It is difficult to validate a technique to assess tooth inclination as the traditionally used radiographic assessment is well known to be less than ideal.[52] There is a problem in assessing validity of the Mounted Angle Protractor against the radiograph when the validity of the cephalometric technique itself may be questioned. Nevertheless, cephalometry is a technique which is commonly used throughout the world and any new technique can be compared with it. In addition the radiographic technique usually records the most prominent incisor and there may be superimposition and lack of clarity between the apices of the six anterior teeth.

With the availability of CBCT the technique validation is no more difficult. Although both techniques assess tooth inclination, the Mounted Angle Protractor records crown inclination only and the CBCT assess crown/root inclination. The device can record the individual inclinations of all maxillary teeth allowing more detailed assessment of proclined or retroclined teeth.

Costalos et al.[98] evaluated the correlations between the OrthoCad and the manual technique in the measurements of the American Board of Orthodontics' objective grading system criteria. They observed a statistically significant difference when measuring alignment and buccolingual inclination of the teeth between the plaster and digital models. Moreover, in a similar study, Okunami et al.[99] excluded the buccolingual inclination of the teeth from the comparison of the 2 methods because they believed that Ortho Cad was not capable of measuring this index according to American Board of Orthodontics' criteria. This issue is probably due to the different methods of assessment of the buccolingual inclination relative to a horizontal line passing through the corresponding cusp tip. Thus, when recording the buccolingual inclination in the manual and 3D methods, using a reference plane instead of the line connecting the corresponding cusp tips increases the similarity of the 2 techniques. Furthermore, Kodaka et al.[100] compared the inclination of tooth crowns according to the method of Andrews,[5] using a 3D laser scanner and Octane (Silicon Graphics) software with the manual technique and a conveyor in their study. They found no significant difference in the mean value of the 2 methods; however, the variance of the 3D method was higher than the manual technique.

On the other hand, considering the popularity of CBCT because of its lower costs and radiation doses, it is now possible to accurately assess the crown and root 3 dimensionally.[101] Shewinvanakitkul et al.[90] measured the inclination of the mandibular canines and the first molars using CBCT, with the mandibular plane as the reference plane. The reliability of this technique was reported to be excellent. In general, in studies assessing tooth inclinations on the casts, the occlusal plane was used, and in radiographic studies, skeletal planes have been used. Considering the change of occlusal plane during orthodontic treatment, this plane does not have enough stability to be used as a reference plane for measuring tooth inclination. Furthermore, use of radiographic techniques such as CBCT has 2 drawbacks: exposure to the ionizing beam and feasibility of application.

Overall, since the standard deviations of the measurements for all teeth were greater than the differences between the measurements made with the 2 methods and, also, greater than the reliability of each technique alone, it seems that both the TIP and the 3D software have clinically acceptable accuracy for measuring the inclinations of teeth.[58]

Comparisons indicate that assessing faciolingual inclination using dental casts is a method that is sufficiently reliable.[44] This study also show the functional enmeshments between different faciolingual inclination measurements and all tooth characteristics relevant for orthodontic treatment, such as crown, root, or entire tooth inclination. That is, they are suitable for calculating the different tooth features on the basis of individual cast measurements, accurately and without the need for additional radiation exposure. The predictability of the different tooth features may be beneficial for orthodontists in determining treatment plans.[44]

In this study, the faciolingual inclinations of incisors, canines, and premolars, in 30 maxillary dental casts were determined by a manual technique with the Mounted Angle Protractor and compared with the CBCT determined values. The Mounted Angle Protractor records crown inclination only. However, the device can record the individual inclinations of all maxillary teeth allowing more detailed assessment of proclined or retroclined teeth. The correlations between the two techniques and the reliability of each method were evaluated.

The coronal landmarks used in the two methods were equal, and the facial axis points were used for this purpose. Occlusal plane was used as the horizontal reference plane. In the CBCT software, a plane similar to that suggested by Andrews[5] and applied by Sjogren et al.[105] was used.

## FACIOLINGUAL INCLINATION

### Maxillary central incisors

The faciolingual inclination of the maxillary central incisor crown measured using the protractor was 9.36º ± 2.18º and using CBCT was 9.92º ± 2.34º. The protractor measurement was marginally lower than the CBCT measurement and the statistical analysis did not report any significant difference.

### Maxillary lateral incisors

The faciolingual inclination of the maxillary lateral incisor crown measured using the protractor was 7.40º ± 1.99º and using CBCT was 7.49º ± 2.35º. The protractor measurement was marginally lower than the CBCT measurement and the statistical analysis did not report any significant difference.

**Maxillary canine**

The faciolingual inclination of the maxillary canine crown measured using the protractor was 10.76º ± 1.97º and using CBCT was 10.94º ± 1.97º. The protractor measurement was marginally lower than the CBCT measurement and the statistical analysis did not report any significant difference.

**Maxillary first premolar**

The faciolingual inclination of the maxillary 1$^{st}$ premolar crown measured using the protractor was 10.80º ± 2.02º and using CBCT was 11.16º ± 2.18º. The protractor measurement was marginally lower than the CBCT measurement and the statistical analysis did not report any significant difference.

**Maxillary second premolar**

The faciolingual inclination of the maxillary 2$^{nd}$ premolar crown measured using the protractor was 10.86º ± 2.02º and using CBCT was 11.50º ± 2.25º. The protractor measurement was marginally lower than the CBCT measurement and the statistical analysis did not report any significant difference.

**Tooth inclination**

Tooth inclination was measured using CBCT. The protractor cannot measure the tooth inclination as it can only assess the crown and not the root. Tooth inclination values were higher than the crown inclination values.

The faciolingual inclination values obtained using Mounted Angle Protractor for each tooth was comparable to the values obtained using Tooth Inclination Protractor in the study by Nouri et al.[58] The CBCT derived values of faciolingual inclination of the crown was also comparable with the 3D measurements made in the study by Nouri et al.[58]

The faciolingual inclination of premolars obtained using the Mounted Angle Protractor was comparable to the buccolingual inclination of premolars obtained using a modified universal bevel protractor in the Shu et al.[55] study.

The faciolingual inclination values obtained using Mounted Angle Protractor for each tooth was in contrary to the values given by Andrews[5] and Currim et al.[54]

Upper crown inclinations in this study were significantly greater. All maxillary teeth from central incisors to premolars showed increased faciolingual inclination when compared to the Andrews[5] data. This could probably be due to the difference in arch forms found in different populations and also due to differences in the methodology used for measurement.

Tong et al.[41] measured mesiodistal angulation and faciolingual inclination of each whole tooth in 3- dimensional space in patients with near-normal occlusion. Tooth inclination values of central incisors and lateral incisors obtained using CBCT in this study was comparable to the values in the Tong et al.[41] and the tooth inclination values of canine and premolars were not comparable. This could be due to variation in the sample as well as the methodology used.

The differences in measurement by Mounted Angle Protractor and CBCT although statistically insignificant does not indicate the clinical insignificance. A fixed horizontal reference plane is important, especially for the measurement of alterations in tooth inclinations after orthodontic treatment.[51]The customized mounted angle protractor designed for this study has a horizontal arm to which the protractor was attached. The horizontal arm was parallel to the platform with the rotating table. This ensures that errors due to manual positing of protractor while taking measurements in the casts was minimized. It also ensured that all the casts were measured by the similar setup and errors was minimized.

The previous studies by Richmond et al[52], Ghahferokhi et al[53], Shu et al[55], Nouri et al[58] lacked a fixed horizontal reference plane which was overcome by this study. An added advantage was that the height of the horizontal arm could be adjusted with the vertical lead screw attachment. The rotating table on the platform which held the cast could also be adjusted while measuring.

The risk to data reliability and reproducibility due to hand held components[5, 52] was also eliminated by using the custom made Mounted Angle Protractor. Dental cast based methods for measuring the faciolingual inclination by Andrews[5] was time consuming and difficult compared to this study.

In recent years, CBCT technology has been used in orthodontics, and the volumetric images obtained from CBCT scans have been shown to display dentofacial structures in a 1:1 ratio, and distortions, if any, are clinically insignificant.[35, 36] Van Elslande et al.[43] measured the angulation of the typodont teeth from the panoramic-like images constructed from CBCT scans and compared them with the coordinate measuring machine's measurements. It was concluded that the constructed panoramic-like images were more accurate than the conventional panoramic radiographs in assessing tooth angulation. Tong et al.[40] developed the USC root vector analysis program to measure each whole tooth's mesiodistal angulation and faciolingual inclination directly from the CBCT volumetric images. Tooth inclination values obtained from CBCT in this study was comparable to the values obtained by Tong et al.[41]

Comparing the faciolingual inclination of the crown obtained from the custom made mounted angle protractor with CBCT derived values helped to establish the reliability and accuracy of the new device. The values obtained from CBCT was marginally higher compared to the values obtained from the custom made mounted angle protractor but the difference was statistically insignificant.

The results indicated that both the values were comparable. The Mounted Angle Protractor can be used as a new tool for measuring faciolingual inclination of each tooth crown in patients. In addition, this new tool can also be used to compare the outcomes of various treatment modalities: e.g.; surgical treatment vs camouflage, and extraction vs non-extraction. We can also compare the norms of different ethnic groups to set ethnic-specific goals for patients with different backgrounds.

The variations in our results when compared with those available in literature could be due to variations in the biological variables such as, crown morphology, (facial contour) difference among individuals or among populations and the crown-root angle which differed among teeth of the same type, as suggested by Germane et al.[11]

**Limitations of the study**

- Measuring the FACCs inclinations was time consuming and required numerous steps for measuring the angulations and was potentially prone to error. Occlusal plane needed to be chosen, with the cast trimmed parallel to this occlusal plane.
- Measuring the inclination of an axis tangent to a convex surface was controversial because the definition of a tangent to a convex, irregular surface might lead to inaccurate measures that are often difficult to replicate.
- Estimating a tooth's local relationship with 'critical' hard tissue borders, such as upper incisor roots to the palatal cortical plate is difficult. There is still a need for careful clinical and radiographic evaluation of hard and soft tissue borders and anterior teeth. Inclination assessments on dental casts are therefore not intended to substitute for lateral radiographs, but they may be suitable for reducing the number of consecutive radiographs.
- Mounted Angle Protractor cannot be used for measuring faciolingual inclination of teeth in patient casts with severe crowding.

**Future scope of the study**

- The Mounted Angle Protractor can be used for measuring faciolingual inclination of crown and thus could provide guidance for orthodontic treatment planning and finishing.
- Faciolingual inclination of teeth in different malocclusion can be evaluated in future studies.
- The Mounted Angle Protractor assessment may also be used as a clinical or research tool in assessing incisor correction during or at the end of treatment.
- Crown angulation measurement with such a device have to be evaluated in future studies.
- The achievement of individualized treatment objectives can be enhanced with such a tool.
- In cases where CBCT evaluation is not mandatory, the crown inclination can be obtained using the Mounted Angle Protractor.
- The Mounted Angle Protractor will also help in avoiding the need for radiographs for assessing crown inclination.

# ***Conclusion***

# CONCLUSION

From the results of this study it can be inferred that the values obtained were comparable and there was excellent positive correlation between crown inclination measured by CBCT & the Mounted Angle Protractor**.**

Thus it can be concluded that the Mounted Angle Protractor is a reliable and valid measure for assessing the faciolingual inclination of maxillary teeth. It may also be used to record changes of inclination during treatment process. Thus, assessing third order angles on dental casts is a sufficiently reliable method and one that is appropriate for routine orthodontic practice and additional exposure to radiation can be avoided.

# ***References***

1. Tong H, Kwon D, Shi J, Sakai N, Enciso R, Sameshima GT. Mesiodistal angulation and faciolingual inclination of each whole tooth in 3-dimensional space in patients with near-normal occlusion. American Journal of Orthodontics and Dentofacial Orthopedics. 2012 May 1;141(5):604-17.

2. Andrews LF. The six keys to normal occlusion. American Journal of Orthodontics and Dentofacial Orthopedics. 1972 Sep 1;62(3):296-309.

3. Andrews LF. The diagnostic system: occlusal analysis. Dental Clinics of North America. 1976 Oct 1;20(4):671-90.

4. Andrews LF. The straight-wire appliance. British journal of orthodontics. 1979 Jul;6(3):125-43.

5. Andrews LF. Straight wire: the concept and appliance. (No Title). 1989.

6. Magness WB. The straight-wire concept. American journal of orthodontics. 1978 May 1;73(5):541-50.

7. Kattner PF, Schnelder BJ. Comparison of Roth appliance and standard edgewise appliance treatment results. American Journal of Orthodontics and Dentofacial Orthopedics. 1993 Jan 1;103(1):24-32.

8. Balut N, Klapper L, Sandrik J, Bowman D. Variations in bracket placement in the preadjusted orthodontic appliance. American journal of orthodontics and dentofacial orthopedics. 1992 Jul 1;102(1):62-7.

9. Miethke RR. Third order tooth movements with straight wire appliances: Influence of vestibular tooth crown morphology in the vertical plane. Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie. 1997 Jul;58:186-97.

10. Miethke RR, Melsen B. Effect of variation in tooth morphology and bracket position on first and third order correction with preadjusted appliances. American Journal of Orthodontics and Dentofacial Orthopedics. 1999 Sep 1;116(3):329-35.

11. Germane N, Bentley B, Isaacson RJ, Revere Jr JH. The morphology of canines in relation to preadjusted appliances. The Angle Orthodontist. 1990 Mar 1;60(1):49-54

12. Carlsson R, Ro A. Crown-root angles of upper central incisors. American Journal of Orthodontics. 1973 Aug 1;64(2):147-54.

13. Bryant RM, Sadowsky PL, Dent M, Hazelrig JB. Variability in three morphologic features of the permanent maxillary central incisor. American Journal of Orthodontics. 1984 Jul 1;86(1):25-32.

14. Mayoral G. Treatment results with light wires studied by panoramic radiography. American journal of orthodontics. 1982 Jun 1;81(6):489-97.

15. Ursi WJ, Almeida RR, Tavano O, Henriques JF. Assessment of mesiodistal axial inclination through panoramic radiography.

16. Lucchesi MV, Wood RE, Nortje CJ. Suitability of the panoramic radiograph for assessment of mesiodistal angulation of teeth in the buccal segments of the mandible. American Journal of Orthodontics and Dentofacial Orthopedics. 1988 Oct 1;94(4):303-10.

17. Mckee IW, Williamson PC, Lam EW, Heo G, Glover KE, Major PW. The accuracy of 4 panoramic units in the projection of mesiodistal tooth angulations. American journal of orthodontics and dentofacial orthopedics. 2002 Feb 1;121(2):166-75.

18. Owens AM, Johal A. Near-end of treatment panoramic radiograph in the assessment of mesiodistal root angulation. The Angle Orthodontist. 2008 May 1;78(3):475-81.

19. Garcia-Figueroa MA, Raboud DW, Lam EW, Heo G, Major PW. Effect of buccolingual root angulation on the mesiodistal angulation shown on panoramic radiographs. American journal of orthodontics and dentofacial orthopedics. 2008 Jul 1;134(1):93-9.

20. Steiner CC. Cephalometrics in clinical practice. The Angle Orthodontist. 1959 Jan 1;29(1):8-29.

21. Knösel M, Jung K, Attin T, Attin R, Kubein-Meesenburg D, Gripp-Rudolph L. Systematic evaluation of the features influencing the accuracy of third order measurements. The European Journal of Orthodontics. 2009 Oct 1;31(5):547-55.

22. Lascala CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dentomaxillofacial Radiology. 2004 Sep;33(5):291-4.

23. Hutchinson SY. Cone beam computed tomography panoramic images vs. traditional panoramic radiographs. American Journal of Orthodontics and Dentofacial Orthopedics. 2005 Oct 1;128(4):550..

24. Lagravère MO, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. American Journal of Orthodontics and Dentofacial Orthopedics. 2008 Jul 1;134(1):112-6.

25. Mestriner MA, Enoki C, Mucha JN. Normal torque of the buccal surface of mandibular teeth and its relationship with bracket positioning: a study in normal occlusion. Brazilian Dental Journal. 2006;17:155-60.

26. Peck S, Peck H. Crown dimensions and mandibular incisor alignment. The Angle Orthodontist. 1972 Apr 1;42(2):148-53.

27. Dellinger EL. A scientific assessment of the straight-wire appliance. American journal of orthodontics. 1978 Mar 1;73(3):290-9.

28. Morrow JB. The angular variability of the facial surfaces of the human dentition: an evaluation of the morphological assumptions implicit in the various" straight wire techniques". St. Louis University. School of Dentistry; 1978.

29. Bryant RM, Sadowsky PL, Dent M, Hazelrig JB. Variability in three morphologic features of the permanent maxillary central incisor. American Journal of Orthodontics. 1984 Jul 1;86(1):25-32.

30. Vardimon AD, Lambertz W. Statistical evaluation of torque angles in reference to straight-wire appliance (SWA) theories. American journal of orthodontics. 1986 Jan 1;89(1):56-66.

31. Germane N, Bentley Jr BE, Isaacson RJ. Three biologic variables modifying faciolingual tooth angulation by straight-wire appliances. American Journal of Orthodontics and Dentofacial Orthopedics. 1989 Oct 1;96(4):312-9.

32. Ross VA, Isaacson RJ, Germane N, Rubenstein LK. Influence of vertical growth pattern on faciolingual inclinations and treatment mechanics. American Journal of Orthodontics and Dentofacial Orthopedics. 1990 Nov 1;98(5):422-9.

33. Uğur T, Yukay F, of Orthodontics FD, of Dentistry S. Normal faciolingual inclinations of tooth crowns compared with treatment groups of standard and pretorqued brackets. American Journal of Orthodontics and Dentofacial Orthopedics. 1997 Jul 1;112(1):50-7.

34. Carlsson R, Ro A. Crown-root angles of upper central incisors. American Journal of Orthodontics. 1973 Aug 1;64(2):147-54.

35. Lascala CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dentomaxillofacial Radiology. 2004 Sep;33(5):291-4.

36. Lagravère MO, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. American Journal of Orthodontics and Dentofacial Orthopedics. 2008 Jul 1;134(1):112-6.

37. Mckee IW, Williamson PC, Lam EW, Heo G, Glover KE, Major PW. The accuracy of 4 panoramic units in the projection of mesiodistal tooth angulations. American journal of orthodontics and dentofacial orthopedics. 2002 Feb 1;121(2):166-75.

38. Garcia-Figueroa MA, Raboud DW, Lam EW, Heo G, Major PW. Effect of buccolingual root angulation on the mesiodistal angulation shown on panoramic radiographs. American journal of orthodontics and dentofacial orthopedics. 2008 Jul 1;134(1):93-9.

39. Owens AM, Johal A. Near-end of treatment panoramic radiograph in the assessment of mesiodistal root angulation. The Angle Orthodontist. 2008 May 1;78(3):475-81.

40. Tong H, Enciso R, Van Elslande D, Major PW, Sameshima GT. A new method to measure mesiodistal angulation and faciolingual inclination of each whole tooth with volumetric cone-beam computed tomography images. American journal of orthodontics and dentofacial orthopedics. 2012 Jul 1;142(1):133-43.

41. Tong H, Kwon D, Shi J, Sakai N, Enciso R, Sameshima GT. Mesiodistal angulation and faciolingual inclination of each whole tooth in 3-dimensional space in patients with near-normal occlusion. American Journal of Orthodontics and Dentofacial Orthopedics. 2012 May 1;141(5):604-17.

42. Schlicher W, Nielsen I, Huang JC, Maki K, Hatcher DC, Miller AJ. Consistency and precision of landmark identification in three-dimensional cone beam computed tomography scans. The European Journal of Orthodontics. 2012 Jun 1;34(3):263-75.

43. Van Elslande D, Heo G, Flores-Mir C, Carey J, Major PW. Accuracy of mesiodistal root angulation projected by cone-beam computed tomographic panoramic-like images. American Journal of Orthodontics and Dentofacial Orthopedics. 2010 Apr 1;137(4):S94-9.

44. Knösel M, Jung K, Attin T, Attin R, Kubein-Meesenburg D, Gripp-Rudolph L. Systematic evaluation of the features influencing the accuracy of third order measurements. The European Journal of Orthodontics. 2009 Oct 1;31(5):547-55.

45. Lucchesi MV, Wood RE, Nortje CJ. Suitability of the panoramic radiograph for assessment of mesiodistal angulation of teeth in the buccal segments of the mandible. American Journal of Orthodontics and Dentofacial Orthopedics. 1988 Oct 1;94(4):303-10.

46. Ursi WJ, Almeida RR, Tavano O, Henriques JF. Assessment of mesiodistal axial inclination through panoramic radiography. Journal of Clinical Orthodontics. 1990 Mar;24(3):166-73.

47. Al-Abdwani R, Moles DR, Noar JH. Change of incisor inclination effects on points A and B. The Angle Orthodontist. 2009 May 1;79(3):462-7.

48. Mestriner MA, Enoki C, Mucha JN. Normal torque of the buccal surface of mandibular teeth and its relationship with bracket positioning: a study in normal occlusion. Brazilian Dental Journal. 2006;17:155-60.

49. Janson G, Bombonatti R, Cruz KS, Hassunuma CY, Del Santo Jr M. Buccolingual inclinations of posterior teeth in subjects with different facial patterns. American journal of orthodontics and dentofacial orthopedics. 2004 Mar 1;125(3):316-22.

50. Shah N, Spary DJ, Rock WP. A jig for measuring incisor inclination. The European Journal of Orthodontics. 2005 Jun 1;27(3):252-7.

51. Ferrario VF, Sforza C, Colombo A, Ciusa V, Serrao G. Three-dimensional inclination of the dental axes in healthy permanent dentitions—a cross-sectional study in a normal population. The Angle Orthodontist. 2001 Aug 1;71(4):257-64.

52. Richmond S, Klufas ML, Sywanyk M. Assessing incisor inclination: a non-invasive technique. The European Journal of Orthodontics. 1998 Dec 1;20(6):721-6.

53. Ghahferokhi AE, Elias L, Jonsson S, Rolfe B, Richmond S. Critical assessment of a device to measure incisor crown inclination. American journal of orthodontics and dentofacial orthopedics. 2002 Feb 1;121(2):185-91.

54. Currim S, Wadkar PV. Objective assessment of occlusal and coronal characteristics of untreated normals: a measurement study. American journal of orthodontics and dentofacial orthopedics. 2004 May 1;125(5):582-8.

55. Shu R, Han X, Wang Y, Xu H, Ai D, Wang L, Wu Y, Bai D. Comparison of arch width, alveolar width and buccolingual inclination of teeth between Class II division 1 malocclusion and Class I occlusion. The Angle orthodontist. 2013 Mar 1;83(2):246-52.

56. Cao L, Zhang K, Bai D, Jing Y, Tian Y, Guo Y. Effect of maxillary incisor labiolingual inclination and anteroposterior position on smiling profile esthetics. The Angle Orthodontist. 2011 Jan 1;81(1):121-9.

57. Hussels W, Nanda RS. Effect of maxillary incisor angulation and inclination on arch length. American Journal of Orthodontics and Dentofacial Orthopedics. 1987 Mar 1;91(3):233-9.

58. Nouri M, Abdi AH, Farzan A, Mokhtarpour F, Baghban AA. Measurement of the buccolingual inclination of teeth: manual technique vs 3-dimensional software. American journal of orthodontics and dentofacial orthopedics. 2014 Oct 1;146(4):522-9.

59. Verma S, Singh SP, Utreja A. A normative study to evaluate inclination and angulation of teeth in North Indian population and comparision of expression of torque in preadjusted appliances. Journal of orthodontic science. 2014 Jul 1;3(3):81-8.

60. Xu H, Han X, Wang Y, Shu R, Jing Y, Tian Y, Andrews WA, Andrews LF, Bai D. Effect of buccolingual inclinations of maxillary canines and premolars on perceived smile attractiveness. American Journal of Orthodontics and Dentofacial Orthopedics. 2015 Feb 1;147(2):182-9.

61. Najafi HZ, Oshagh M, Khalili MH, Torkan S. Esthetic evaluation of incisor inclination in smiling profiles with respect to mandibular position. American Journal of Orthodontics and Dentofacial Orthopedics. 2015 Sep 1;148(3):387-95.

62. Jain M, Vyas M, Singh JR. Effect of crown angulation of maxillary incisor on effective arch perimeter. Journal of Clinical and Diagnostic Research: JCDR. 2017 Jun;11(6):ZC92.

63. Bukhary F, Bukhary MT, Albarakati S. Estimation and comparative evaluation of tip and torque values of Saudis for bracket prescription. The Saudi Dental Journal. 2021 Dec 1;33(8):1133-41.

64. Sivanandam M, Venkata KV, Rajendran R, Arafath MM, Sudhakar V, Chinnasamy A, Mallela SS, Babu SJ, Swarnalatha C, Nayyar AS. Comparative evaluation of variations in torque expression in maxillary incisor and canine using different bracket prescriptions placed at different crown levels by finite element (FE) method: An in-vitro analysis. Journal of Orthodontic Science. 2023 Nov 1;12(1):72.

65. Golshah A, Rezaei N, Heshmati S. Buccolingual inclination of canine and first and second molar teeth and the curve of Wilson in different sagittal skeletal patterns of adults using cone-beam computed tomography. International journal of dentistry. 2020 Oct 31;2020.

66. Al-Mashhadany SM, Saloom JE, Nahidh M. The relation among teeth and maxillary dental arch dimensions with anterior teeth angulation and inclination. The Scientific World Journal. 2021 Oct 5;2021:1-5.

67. O'Higgins EA, Kirschen RH, Lee RT. The influence of maxillary incisor inclination on arch length. British Journal of Orthodontics. 1999 May;26(2):97-102.

68. Gioka C, Eliades T. Materials-induced variation in the torque expression of preadjusted appliances. American Journal of Orthodontics and Dentofacial Orthopedics. 2004 Mar 1;125(3):323-8.

69. Kragskov J, Bosch C, Gyldensted C, Sindet-Pedersen S. Comparison of the reliability of craniofacial anatomic landmarks based on cephalometric radiographs and three-dimensional CT scans. The Cleft palate-craniofacial journal. 1997 Mar;34(2):111-6.

70. Adams GL, Gansky SA, Miller AJ, Harrell Jr WE, Hatcher DC. Comparison between traditional 2-dimensional cephalometry and a 3-dimensional approach on human dry skulls. American journal of orthodontics and dentofacial orthopedics. 2004 Oct 1;126(4):397-409.

71. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. Journal-Canadian Dental Association. 2006 Feb 1;72(1):75.

72. Moshiri M, Scarfe WC, Hilgers ML, Scheetz JP, Silveira AM, Farman AG. Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone-beam computed tomography. American Journal of Orthodontics and Dentofacial Orthopedics. 2007 Oct 1;132(4):550-60.

73. Periago DR, Scarfe WC, Moshiri M, Scheetz JP, Silveira AM, Farman AG. Linear accuracy and reliability of cone beam CT derived 3-dimensional images constructed using an orthodontic volumetric rendering program. The Angle Orthodontist. 2008 May 1;78(3):387-95.

74. Berco M, Rigali Jr PH, Miner RM, DeLuca S, Anderson NK, Will LA. Accuracy and reliability of linear cephalometric measurements from cone-beam computed tomography scans of a dry human skull. American Journal of Orthodontics and Dentofacial Orthopedics. 2009 Jul 1;136(1):17-e1.

75. Gribel BF, Gribel MN, Frazão DC, McNamara Jr JA, Manzi FR. Accuracy and reliability of craniometric measurements on lateral cephalometry and 3D measurements on CBCT scans. The Angle Orthodontist. 2011 Jan 1;81(1):26-35..

76. Ludlow JB, Walker C. Assessment of phantom dosimetry and image quality of i-CAT FLX cone-beam computed tomography. American journal of orthodontics and dentofacial orthopedics. 2013 Dec 1;144(6):802-17.

77. Jung YH, Cho BH, Hwang JJ. Analysis of the root position of the maxillary incisors in the alveolar bone using cone-beam computed tomography. Imaging science in dentistry. 2017 Sep;47(3):181.

78. Sendyk M, de Paiva JB, Abrao J, Neto JR. Correlation between buccolingual tooth inclination and alveolar bone thickness in subjects with Class III dentofacial deformities. American Journal of Orthodontics and Dentofacial Orthopedics. 2017 Jul 1;152(1):66-79.

79. Baumrind S, Frantz RC. The reliability of head film measurements: 1. Landmark identification. American journal of orthodontics. 1971 Aug 1;60(2):111-27.

80. Baumrind S, Frantz RC. The reliability of head film measurements: 2. Conventional angular and linear measures. American journal of orthodontics. 1971 Nov 1;60(5):505-17..

81. Houston WJB. The analysis of errors in orthodontics measure ments. American journal of orthodontics 1983;83:382-90.

82. Carey CW. Diagnosis and case analysis in orthodontics. American Journal of Orthodontics. 1952 Mar 1;38(3):149-61.

83. Lundström A. Intermaxillary tooth width ratio and tooth alignment and occlusion. Acta Odontologica Scandinavica. 1955 Jan 1;12(3-4):265-92.

84. Lear CS. Three-dimensional analysis of changes in location of crowns and root apices of maxillary central incisors. The Angle Orthodontist. 1976 Oct 1;46(4):338-44..

85. Richmond S, Jones ML. A comparison of two-and three-dimensional incisor angles. British Journal of Orthodontics. 1985 Apr 1;12(2):90-6.

86. Richmond S. Recording the dental cast in three dimensions. American Journal of Orthodontics and Dentofacial Orthopedics. 1987 Sep 1;92(3):199-206.

87. Bennett DT, Smales FC. Orientated study models. The Dental practitioner and dental record. 1968 Jun;18(10):353-5.

88. Perera PS. Orienting dental casts to cephalometric radiographs. The Angle Orthodontist. 1981 Jul 1;51(3):246-51.

89. Richmond S, Klufas ML, Sywanyk M. Assessing incisor inclination: a non-invasive technique. The European Journal of Orthodontics. 1998 Dec 1;20(6):721-6.

90. Shewinvanakitkul W, Hans MG, Narendran S, Martin Palomo J. Measuring buccolingual inclination of mandibular canines and first molars using CBCT. Orthodontics & craniofacial research. 2011 Aug;14(3):168-74.

91. Nouri M, Hosseini SK, Asefi S, Abdi AH, Bagheban AA. Three-dimensional measurement of tooth inclination: A longitudinal study. Dental Research Journal. 2019 Jul 1;16(4):225-32.

92. Lombardo L, Perri A, Arreghini A, Latini M, Siciliani G. Three-dimensional assessment of teeth first-, second-and third-order position in Caucasian and African subjects with ideal occlusion. Progress in Orthodontics. 2015 Dec;16:1-2.

93. Huanca Ghislanzoni LT, Lineberger M, Cevidanes LH, Mapelli A, Sforza C, McNamara JA. Evaluation of tip and torque on virtual study models: a validation study. Progress in Orthodontics. 2013 Dec;14:1-6.

94. Silva MA, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. American Journal of Orthodontics and Dentofacial Orthopedics. 2008 May 1;133(5):640-e1.

95. Gull MA, Yaqoob M, Mushtaq M, Maqbool S. Buccolingual Inclination of Maxillary and Mandibular First Molars in Untreated Adults: A CBCT Study. International Journal of Contemporary Medical Research. 2019;6:10-3.

96. Ribeiro GL, Locks A, Pereira J, Brunetto M. Analysis of rapid maxillary expansion using cone-beam computed tomography. Dental Press Journal of Orthodontics. 2010;15:107-12.

97. De Vos W, Casselman J, Swennen G. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. International journal of oral and maxillofacial surgery. 2009 Jun 1;38(6):609-25.

98. Costalos PA, Sarraf K, Cangialosi TJ, Efstratiadis S. Evaluation of the accuracy of digital model analysis for the American Board of Orthodontics objective grading system for dental casts. American Journal of Orthodontics and Dentofacial Orthopedics. 2005 Nov 1;128(5):624-9.

99. Okunami TR, Kusnoto B, BeGole E, Evans CA, Sadowsky C, Fadavi S. Assessing the American Board of Orthodontics objective grading system: digital vs plaster dental casts. American Journal of Orthodontics and Dentofacial Orthopedics. 2007 Jan 1;131(1):51-6.

100. Kodaka K, Nishii Y, Sakurai Y, Nojima K, Sueishi K. Crown inclination measured by laser scanner. orthodontic waves. 2010 Mar 1;69(1):8-12.

101. German DS, German J. Cone-beam volumetric imaging: a two-minute drill. Journal of Clinical Orthodontics: JCO. 2010 Apr 1;44(4):253-65..

102. Bai D, Xiao L, Chen Y. A study on central zone contour of tooth-crown vesticular surface among young people with normal occlusion. Sheng wu yi xue Gong Cheng xue za zhi= Journal of Biomedical Engineering= Shengwu Yixue Gongchengxue Zazhi. 2002 Jun 1;19(2):287-90.

103. Fukagawa H, Motegi E, Fuma A, Nomura M, Kano M, Sueishi K, Okano S. Tooth inclination in elderly with many remaining teeth observed by 3-D imaging. The Bulletin of Tokyo Dental College. 2010;51(2):69-76..

104. Brezniak N, Turgeman R, Redlich M. Incisor inclination determined by the light reflection zone on the tooth's surface. Quintessence International. 2010 Jan 1;41(1).

105. Sjögren AP, Lindgren JE, Huggare JÅ. Orthodontic study cast analysis reproducibility of recordings and agreement between conventional and 3D virtual measurements. Journal of digital imaging. 2010 Aug;23:482-92.

# ***Annexures***

# *Annexure 1*: Informed Consent (Malayalam)

**<u>സമ്മതപത്രം</u>**

സെന്റ് ഗ്രിഗോറിയസ് ഡെന്റൽ കോളേജിലെ, ഓർത്തോഡോണ്ടിക്സ് വിഭാഗം നടത്തുന്ന മേൽ താടിയിലെ പല്ലുകളുടെ ചരിവ് മൗണ്ടഡ് ആംഗിൾ പൊട്രാക്ടർ ഉം സിബി സിറ്റിയും ഉപയോഗിച്ച് താരതമ്യം ചെയ്യുന്ന പഠനത്തിൽ എന്റെ മകൾ/മകന്……................... പങ്കെടുക്കാൻ എനിക്ക് സമ്മതമാണ്. പഠനത്തെക്കുറിച്ചുള്ള എല്ലാ വിവരങ്ങളും എനിക്ക് അറിയാവുന്ന ഭാഷയിൽ എന്നോട് വിവരിച്ചിട്ടുണ്ട്. ഏത് നിമിഷവും പഠനത്തിൽ നിന്നും പിന്മാറാം എന്നും, ഇത് തുടർന്നുള്ള എന്റെ മകളുടെ / മകന്റെ ചികിത്സയെ ബാധിക്കില്ലെന്നും, ചികിത്സാ വിവരങ്ങളുടെ സ്വകാര്യത നഷ്ടപ്പെടുത്താതെ സൂക്ഷിക്കുമെന്നും ഉറപ്പ് നൽകിയിട്ടുണ്ട്. ഇതിന്റെ ഭാഗമായി സി. ബി. സി. റ്റി എടുക്കുന്നതിനും പ്രസിദ്ധീകരണങ്ങളിൽ പ്രസിദ്ധീകരിക്കുന്നതിനും എനിക്ക് സമ്മതമാണ്.

പേര്

ഒപ്പ്/വിരലടയാളം

രക്ഷകർത്താവിന്റെ പേര്

ഒപ്പ്/വിരലടയാളം

തിയതി

പരിശോധകന്റെ പേര്

ഒപ്പ്/വിരലടയാളം

സാക്ഷിയുടെ പേര്

ഒപ്പ്/വിരലടയാളം

ഡോക്ടർ……………………………..

പിജി വിദ്യാർഥിനി

ഡോക്ടർ………………………………

പ്രൊഫസർ/ഗൈഡ്

# *Annexure 2*: Informed Consent (English)

I ……………………………. aged …………year son/daughter of…………………………………………………. hear by give my consent to be a part of the study "**Comparative evaluation of faciolingual inclination of maxillary teeth using a customized Mounted Angle Protractor with a CBCT software** "held at Department of Orthodontics St. Gregorios Dental college, Kothamangalam.

I have been informed in detail in the language known to me, about the study. My participation in the study is entirely voluntary & my decision not to participate will not have any negative effect on my dental care. I understand that my identity details will be kept confidential & I hereby grant permission /consent to Department of orthodontics & dentofacial orthopaedics to take & use CBCT of me for use in dissertation& for academic publications.

Parent signature/Thumb impression with date:

Patients' signature/Thumb impression with date:

Address

Contact number

<u>WITNESS CERTIFICATE</u>

1.

DR…………………….

(Post graduate student)

DR…………………………

(Professor& guide)

# *Annexure* 3: MASTER CHART

## PROTRACTOR MEASUREMENTS

| SAMPLE NO: | CI | LI | C | PM1 | PM2 |
|---|---|---|---|---|---|
| 1 | 6 | 5 | 9 | 10 | 10 |
| 2 | 8 | 7 | 10 | 8 | 8 |
| 3 | 9 | 7 | 10 | 10 | 10 |
| 4 | 6 | 5 | 8 | 9 | 9 |
| 5 | 10 | 9 | 12 | 10 | 10 |
| 6 | 8 | 6 | 9 | 10 | 10 |
| 7 | 9 | 7 | 10 | 11 | 11 |
| 8 | 10 | 8 | 11 | 12 | 12 |
| 9 | 7 | 5 | 8 | 9 | 9 |
| 10 | 6 | 4 | 7 | 8 | 8 |
| 11 | 11 | 9 | 11 | 12 | 12 |
| 12 | 7 | 6 | 10 | 12 | 12 |
| 13 | 10 | 7 | 9 | 9 | 9 |
| 14 | 9 | 8 | 11 | 10 | 10 |
| 15 | 7 | 6 | 9 | 11 | 11 |
| 16 | 12 | 10 | 13 | 14 | 14 |
| 17 | 7 | 6 | 10 | 9 | 9 |
| 18 | 11 | 7 | 12 | 10 | 11 |
| 19 | 10 | 6 | 11 | 10 | 10 |
| 20 | 10 | 9 | 13 | 12 | 12 |
| 21 | 12 | 10 | 13 | 12 | 12 |
| 22 | 15 | 13 | 16 | 17 | 17 |
| 23 | 13 | 11 | 14 | 15 | 15 |
| 34 | 11 | 7 | 12 | 11 | 12 |
| 25 | 9 | 5 | 10 | 9 | 10 |
| 26 | 12 | 9 | 13 | 11 | 12 |
| 27 | 11 | 9 | 12 | 13 | 12 |
| 28 | 8 | 7 | 11 | 12 | 12 |
| 29 | 9 | 8 | 11 | 9 | 8 |
| 30 | 8 | 6 | 8 | 9 | 9 |

# *Annexure* 4: MASTER CHART

## CBCT MEASUREMENTS – CROWN INCLINATION

| SAMPLE NO: | CI | LI | C | PM1 | PM2 |
|---|---|---|---|---|---|
| 1 | 6.96 | 4.23 | 10.82 | 8.53 | 8.83 |
| 2 | 9.98 | 6.3 | 9.13 | 8.43 | 8.93 |
| 3 | 9.6 | 6.57 | 8.98 | 9.48 | 9.68 |
| 4 | 6.38 | 4.48 | 8.28 | 9.5 | 9.48 |
| 5 | 11.45 | 8.32 | 11.43 | 10.42 | 10.54 |
| 6 | 8.45 | 5.91 | 9.31 | 11.23 | 11.02 |
| 7 | 9.31 | 7.58 | 10.23 | 11.42 | 11.89 |
| 8 | 9.56 | 7.23 | 10.14 | 11.36 | 11.2 |
| 9 | 6.11 | 4.42 | 7.33 | 8.54 | 8.95 |
| 10 | 6.21 | 4.25 | 7.43 | 8.21 | 8.89 |
| 11 | 11.86 | 9.42 | 12.32 | 13.46 | 12.98 |
| 12 | 8.07 | 5.23 | 9.58 | 11.47 | 12.04 |
| 13 | 9.68 | 7.58 | 8.97 | 10.24 | 11.2 |
| 14 | 8.23 | 7.12 | 10.54 | 11.23 | 10.02 |
| 15 | 6.87 | 5.24 | 8.93 | 10.22 | 10.04 |
| 16 | 11.47 | 9.97 | 12.89 | 12.23 | 13.25 |
| 17 | 8.01 | 7.25 | 10.87 | 9.42 | 9.34 |
| 18 | 12.43 | 8.35 | 11.23 | 12.38 | 12.96 |
| 19 | 12.26 | 8.69 | 13.25 | 12.54 | 12.78 |
| 20 | 11.01 | 10.24 | 12.87 | 13.89 | 14.98 |
| 21 | 13.41 | 11.98 | 14.56 | 13.87 | 13.09 |
| 22 | 15.69 | 14.01 | 15.24 | 18.05 | 18.74 |
| 23 | 12.85 | 10.94 | 13.87 | 14.69 | 15.01 |
| 34 | 13.05 | 9.36 | 12.27 | 12.23 | 13.25 |
| 25 | 10.23 | 4.36 | 11.56 | 10.55 | 11.23 |
| 26 | 11.43 | 7.35 | 12.23 | 10.38 | 11.96 |
| 27 | 10.57 | 8.24 | 11.15 | 12.37 | 12.21 |
| 28 | 8.96 | 6.23 | 12.82 | 11.53 | 12.83 |
| 29 | 7.98 | 7.3 | 10.13 | 8.65 | 8.23 |
| 30 | 9.61 | 6.58 | 9.98 | 8.48 | 9.68 |

## *Annexure* 5: MASTER CHART

### CBCT MEASUREMENTS – TOOTH INCLINATION

| SAMPLE NO: | CI | LI | C | PM1 | PM2 |
|---|---|---|---|---|---|
| 1 | 30.34 | 26.47 | 37.7 | 35.48 | 35.28 |
| 2 | 32.44 | 29.7 | 34.54 | 36.26 | 37.63 |
| 3 | 34.21 | 30.64 | 33.34 | 34.28 | 35.41 |
| 4 | 24.26 | 22.38 | 32.61 | 34.56 | 35.66 |
| 5 | 34.41 | 31.25 | 36.53 | 35.23 | 34.43 |
| 6 | 30.34 | 29.23 | 31.56 | 32.22 | 31.41 |
| 7 | 36.33 | 28.41 | 39.44 | 38.12 | 39.02 |
| 8 | 40.01 | 32.63 | 44.28 | 48.25 | 48.3 |
| 9 | 28.32 | 20.58 | 32.54 | 36.74 | 36.25 |
| 10 | 24.56 | 19.24 | 28.21 | 32.45 | 33.02 |
| 11 | 44.23 | 36.99 | 45.23 | 46.02 | 45.06 |
| 12 | 28.65 | 24.23 | 30.24 | 36.44 | 35.24 |
| 13 | 38.21 | 28.24 | 36.24 | 35.23 | 36.14 |
| 14 | 35.21 | 30.21 | 36.24 | 38.78 | 37.01 |
| 15 | 28.01 | 24.15 | 32.21 | 34.29 | 33.87 |
| 16 | 38.23 | 30.25 | 42.21 | 44.21 | 44.87 |
| 17 | 28.94 | 24.57 | 30.14 | 31.24 | 33.25 |
| 18 | 38.42 | 30.12 | 39.47 | 37.54 | 36.24 |
| 19 | 36.14 | 28.56 | 37.45 | 37.5 | 36.58 |
| 20 | 31.91 | 27.45 | 33.54 | 34.27 | 35.87 |
| 21 | 36.23 | 28.27 | 40.28 | 41.29 | 41.87 |
| 22 | 42.23 | 34.25 | 44.21 | 46.21 | 46.87 |
| 23 | 40.21 | 32.14 | 44.25 | 45.12 | 46.36 |
| 34 | 37.1 | 29.53 | 36.44 | 35.51 | 36.59 |
| 25 | 35.15 | 25.57 | 35.46 | 35.51 | 34.59 |
| 26 | 39.42 | 31.12 | 38.47 | 38.54 | 38.24 |
| 27 | 41.02 | 33.64 | 43.29 | 49.26 | 49.31 |
| 28 | 31.34 | 28.47 | 35.7 | 33.48 | 32.28 |
| 29 | 34.45 | 28.71 | 35.55 | 37.25 | 38.67 |
| 30 | 34.22 | 30.65 | 33.35 | 34.29 | 35.42 |

# *Annexure* 6: ETHICAL CLEARANCE CERTIFICATE

**ST. GREGORIOS DENTAL COLLEGE**

UNDER THE MANAGEMENT OF MJSCE TRUST, PUTHENCRUZ

CHELAD , KOTHAMANGALAM, ERNAKULAM DIST, KERALA - 686681

**ETHICAL CLEARANCE CERTIFICATE**

SGDC/152/2022/4344 24/05/2022

To,

Dr.Vidhya K
St. Gregorios Dental College
Chelad, Kothamangalam

Subject: **Ethics Committee Clearance - reg.**

Protocol: Comparative evaluation of faciolingual inclination of maxillary teeth using a customized Mounted Angle Protractor with a CBCT software

After the Institutional Ethics Committee (IEC) held on 24th of May 2022, this study was examined and discussed. After the consideration, the committee had decided to approve and grant clearance for the aforementioned study.

The members who attended the meeting at which the protocol was discussed were:

1) Dr.C.K.K Nair - Former BARC Scientist.
2) Dr.Cinu Thomas A - Scientist, Senior lecturer, Department of Pharmaceutical Sciences Centre for Professional and Advanced Studies.
3) Dr.Lissy Jose - Former member Women's Welfare Association.
4) Adv.Jose Aranjani - Advocate.
5) Dr.Sauganth Paul - Reader, Department of Biochemistry, St.Gregorios Dental College.
6) Dr.Eapen Cherian - Secretary.
7) Dr.Jain Mathew - Principal and Head of the Department, Department of Conservative Dentistry and Endodontics.
8) Dr.George Francis - Head of the Department, Department of Prosthodontics and Crown & Bridge.
9) Dr.Binnoy Kurian - Head of the Department, Department of Orthodontics & Dentofacial Orthopaedics.

Dr. C.K.K Nair
Chairman Institutional Ethics Committee
St.Gregorios Dental College, Chelad

St. Gregorios Dental College, Chelad - 686 681

Dr. Eapen Cherian
Secretary

Phone : 0485-2572529, 530, 531, 2571429, Fax : 0485-2572530,

# *Annexure* 7: ACKNOWLEDGEMENT

"The task of the excellent teacher is to stimulate 'apparently ordinary' people to unusual efforts. The tough problem is not in identifying winners; it is in making winners out of ordinary people."

No endeavor can start, continue and complete without the blessings of Almighty God. At the outset, I thank the almighty for always being by my side by bestowing strength and patience to complete the task entrusted.

I thank with sincere and heartfelt gratitude to my Mentor & Guide, Dr.Binnoy Kurian, Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, St.Gregorios Dental College. During the course of my Post-Graduation study and during this dissertation work, I have obtained his guidance, untiring encouragement and help. His wide knowledge and his logical way of thinking have been of great value for me. His understanding, encouragement and personal guidance have provided a good basis for the present thesis. It is my privilege to be his student and I shall remain indebted all my life for his constant support and guidance.

Thank you Sir, for your everlasting inspiration along with valuable advice and suggestions for improvement in every aspect of this study as well as my entire period of Post-Graduation.

I wish to express my sincere and heartfelt gratitude to my co-guide Dr. Tony Michael, Associate Professor, Department Of Orthodontics and Dentofacial Orthopedics, St.Gregorios Dental College, for his incessant encouragement, unwavering support, brilliant advice and boundless patience. I thank Sir for his wise counsel, never ending willingness to render generous help in carrying out this work and for all the encouragement and timely help rendered during the course of my study.

With gratitude and humbleness, I sincerely thank Dr. Renji K Paul and Dr. Abraham George for their encouragement, useful advice & suggestions. I would like to extend my sincere and heartfelt thanks to Dr. Mathew Jain, Dr. Deaby Miriam and Dr Monisha J for all the encouragement and their timely suggestions and help when required the most.

My Heartfelt thanks to our esteemed Principal Dr.Jain Mathew for his encouragement and support.

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I am deeply obliged to Dr.Saheer, Statistician, for helping me prepare the statistical analysis for this study.

I extend my thanks to the best batch mates I could have ever got Dr. Nisha and Dr. Vidya. I sincerely thank my seniors, Dr Jose Nelson, Dr. Jishnu S, Dr. Kareena Kafeel, Dr.Lisie P Mathew, Dr.Sarjin and Dr. Sreenath, for giving me strength to carry on during this venture. I also thank my juniors Dr.Sunil Skariya, Dr.Shikha, Dr.Dhanya, Dr Sreeba, Dr Srilaxmi and Dr Albert for their cooperation.

Words are inadequate to convey my gratitude to my loving parents, Mr. Kailasan, Mrs. Leelamony and my husband Mr Dhaneesh , without whom I would’t have been where I am today. Without their constant love and support, my degree wouldn’t have been possible.

The full list of those assisted in my thesis would fill many pages. My apologies go with my thanks to those I have omitted.

**Dr. Vidhya K**

## *Annexure* 8: LISTOF ABBREVATIONS

| Sl.no | Abbrevation | Full form |
|---|---|---|
| 1. | CBCT | CONE BEAM COMPUTED TOMOGRAPHY |
| 2. | CT | COMPUTED TOMOGRAPHY |
| 3. | LC | LATERAL CEPHALOGRAPH |
| 4. | MRI | MAGNETIC RESONANCE IMAGING |
| 5. | MBT | MCLAUGHLIN BENNET AND TREVISI |
| 6. | NiTi | NICKEL TITANIUM |
| 7. | PEA | PRE ADJUSTED EDGEWISE APPLIANCE |
| 8. | CI | CENTRAL INCISOR |
| 9. | LI | LATERAL INCISOR |
| 10. | C | CANINE |
| 11. | PM1 | $1^{ST}$ PREMOLAR |
| 12. | PM2 | $2^{ND}$ PREMOLAR |