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Evaluation of Accuracy of Incisor Inclination on the Digital Models, Lateral Cephalograms and Traditional Plaster Model- A Comparative Study

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KEYWORDS

incisor inclination, plaster model, cephalogram, digital model

ABSTRACT:

Aim: To evaluate the accuracy of incisor inclinations on digital models and compare it with the traditional plaster model technique and the lateral cephalogram measurements.

Methodology: A cross-sectional radiography comparison investigation with 50 dental casts of patients with normal and angle's Class I occlusion, as well as lateral cephalograms of the same patients, was

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carried out. All three procedures were used to quantify the maxillary and mandibular incisor inclinations: plaster model (with protractor), lateral cephalogram, and digital model (using Mestro3D Software 5.3 version). The intraclass correlation coefficients between the incisor inclination approaches were examined using the statistical programme IBM SPSS.

Results: The mean maxillary and mandibular inclination with plaster model was 126.06 ± 7.44 mm and 55.14 ± 7.55 mm, with lateral cephalogram was 128.32 ± 7.03 mm and 61.04 ± 6.15 mm, with digital model was 125.30 ±7.58 mm and 60.20 ± 6.75 mm, respectively. A significant correlation for incisor measurement was revealed between plaster and digital mode ($p<0.0001$ for maxillary and $p=0.048$ for mandibular), digital model and lateral cephalogram ($p<0.0001$ for mandibular), plaster model and lateral cephalogram ($p=0.036$ for mandibular).

Conclusion: The study found that maxillary incisor inclinations were highly associated with clay and digital models, but measurements from digital models and lateral cephalograms varied. Mandibular incisor inclination measurements from plaster models and digital models yielded equivalent findings, suggesting digital models should be used.

1. Introduction

Orthodontics is a branch in dentistry dealing with dentition correction, its alignment, facial growth, and occlusion [1]. Theimportance of esthetics among patients has ascended with time. It influences social interaction, occupation, academics, family satisfaction mental health of the patient [2]. Patient's smile is the key indicator of esthetics and a successful orthodontic treatment where the incisors play a foremost role in establishing this smile [3]. The inclination of incisors, significantly affects the lip line. Ricketts observed an increase in the upper lip with increase in the retraction of the upper incisor thereby necessitating a rule of 1 mm increase in lip thickness for every 3 mm of incisor tip retraction. Further, Andrew introduced incisor inclination as one of the six factors of ideal occlusion [4]. The study models are used by the orthodontist to gather information. This involves identifying aberrations, creating the treatment plan's goals, and categorizing the occlusion into several categories in accordance with the categorization scheme. The models aid in examining and visualizing specific teeth morphology and its location within the dental arches. Further, it also benefits in determining the degree of tooth's malposition. These models can be sectioned to assess treatment alternatives thereby signifying their most crucial role in the treatment planning [5]. The tooth inclination protractor (TIP; MBI, Newport, United Kingdom) on dental casts or intraorally, cephalometric angular measurements, conveyor, and compass on casts, and 3-dimensional (3D) methods such as angular measurements on 3D cast models or cone-beam computed tomography (CBCT) can all be used to obtain measurements. [6]. Each method has its own advantages and disadvantages. Plaster models remain the oldest and most traditionally accepted among all the methods, owing to their ability to provide direct and accurate measurements. The ease of obtaining the measurements

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and its affordability further augment its acceptability among dentists and patients. Additionally, these models can be mounted on an articulation to plan a three-dimensional treatment strategy. Despite these advantages, study models are at risk of breakage as they are made of plaster. Storage is another issue that is increasing the cost of this technique. Further, they have poor reproducibility, with the challenge of transferring the details with precision for reuse [7]. Lateral cephalograms are another tool that is extensively used in craniofacial examination [8]. It is used to highlight the morphological characteristics, forecast the facial structure growth, plan the treatment, and assess therapy outcomes [9]. The radiographic technique precisely identifies the anatomical landmark and permits measurements of different angular and linear variables. However, lateral cephalograms define a limitation of errors in identifying landmarks, thereby questioning their validity and reliability [10]. The technological advancement is not far from the field of orthodontics. Since its introduction and acceptance in the orthodontic field, a significant change has been witnessed in the way records are maintained with digital incorporation. Ortho CAD was the first model introduced in 1999, followed by E-models in 2001. One of the best advantages of this technique is that the negative surface models produced by laser scanning the impression's inner surface can be well utilized to build a digital virtual model. With its advantages, digital records have steeply initiated replacing the plaster model technique in various aspects. Being digital, it overcomes the issue of storage, thereby cutting down on storage costs. The digitalized models can be used in patient education with instant retrieval of the measurements. A multidisciplinary approach can be followed by sharing the images of the case via an electronic platform for an open discussion on the treatment plan with the experts in the field. The technique, however, has certain disadvantages. There is a lack of tactile input, and the learning curve with the technique and software is slow. Additionally, the scarcity of digital model supplier companies is evident and comes with an additional cost of software. Furthermore, one of the issues that clinicians are continuously requesting attention for in this field is the correctness of digital models [11]. There is a dearth of information comparing the accuracy of all three approaches, despite research detailing the correctness of digital models, cephalograms, and plaster models separately. Considering this, the present study was conducted to evaluate the accuracy of incisor inclination on digital models and compare it with the traditional plaster model technique and the lateral cephalogram measurements.

Objectives

1. Assessment of maxillary incisor inclination on plaster models, digital models, and

lateral cephalogram.

2. Assessment of mandibular incisor inclination on plaster models, digital models,

and lateral cephalogram.

3. Compare the maxillary and mandibular incisors inclination in all three methods

2. Methods

A cross-sectional radiographic comparative study was conducted at a dental college in Pune, involving 50 dental casts and lateral cephalograms of patients with normal and well-aligned angle's Class I occlusion. The sample size was estimated using XXX software, with a power of 80% and alpha as 0.05. The records were included if they were

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aged 16-25 years, had full complement of permanent dentition with minimal labio-lingual discrepancy, and excluded if the teeth had abnormal tooth morphology, restorations, fractures, cranio-facial anomalies, rotation of the incisors, or Class 2 div II mal-occlusion or open bite.

Data collection included plaster models and lateral cephalograms from previously treated patients and those undergoing orthodontic treatment. Measurements were obtained using a tooth inclination protractor on plaster models, using lateral cephalograms, and using a 3D laser scanner for digital models. The records were divided into two groups and further sub grouped based on comparisons.

The study used a 3D scanner to scan dental casts, digitize them, and import images under each case. The gingival line was marked in the segmentation, and the tooth image was double-clicked to measure its angles. The normality of the data was assessed using the Kolmogorov-Smirnov test using IBM SPSS software version 21. The significance was kept at $p<0.05$.

3. Results

The study included 50 patients, 22 (42%) males and 28 (58%) females with age ranging from 18-25 years. The mean inclination of maxillary and mandibular teeth is presented in Table 1. For maxillary incisor inclination, the intra-class coefficient was 0.686 with a $p<0.0001$ indicates that the measurements obtained by the plaster and digital models were significantly correlated (in agreement). However, an intra-class coefficient of 0.235 with $p= 0.176$ revealed no significant correlation (no agreement) between measurements obtained with digital models and cephalograms. Similarly, an intra-class coefficient of -0.072 with a $p= 0.595$ demonstrated no significant correlation (no agreement) between measurements obtained with plaster models and cephalograms. (Table 1, Figure 3)

With respect to mandibular incisor inclination, an intra-class coefficient of 0.382 with a p-value of 0.048 was obtained, indicating a significant correlation (in agreement) between measurements obtained by the plaster and digital models. However, the correlation coefficient was not too strong. Similarly, the measurements obtained by digital models and cephalograms also demonstrated a significant correlation (in agreement) with the intra-class coefficient of 0.664 and $p<0.0001$. Likewise, the intra-class coefficient was 0.405 with a p-value of 0.036, indicating a significant correlation (in agreement) between plaster models and cephalogram measurements. (Table 1, Figure 3) This suggests a strong association between plaster models and cephalogram measurements.

4. Discussion

Properly positioned teeth that are not crowded and have the right inclination are essential for improving a person's quality of life. Even though maxillary incisor inclination is an important component of the profile view, the research reports differing results about the optimal degree of inclination. While Devanna et al. emphasize the significance of keeping the protruding maxillary teeth in their natural upright position rather than being retracted (retroclination, a sign of ageing due to torque loss), De Velasco et al. report the upright one or the slightly proclined preferred incisor position 12, 13]. Conversely, Cao et al. proposed upright or slightly retroclined incisors, and Doshi et al. proposed an upright position or a mild retroclination [14]. These differences provide a pressing need for accurate measurement of facial characteristics, including tooth alignment, while planning an orthodontic treatment.

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The treatment plan considers both, the facial and skeletal structures. Lateral cephalogram play a crucial role in providing a clear view of the maxillo-mandibular relationship, their relation to the cranial bone, and incisor inclination. Traditional plaster models allow for simpler and direct measurements [15]. whilethe digital models, a ground breaking development aid in understanding the dental morphology, occlusion, and dental relationships which can occasionally be challenging to notice during an intraoral [16].

The mean maxillary incisor inclinations of the plaster and digital models in this study were 126.86 ± 7.44 and 125.30 ± 7.58, respectively, and the measurements they produced demonstrated a strong correlation. Numerous systematic reviews concur with the current study's findings. Both methods were confirmed by the reviews to be extremely accurate in determining the inclination of maxillary teeth. The digital models were considered the new gold standard and adopted in place of traditional plaster models due to their superior accuracy, repeatability, and advantages in terms of cost, time, and space requirements.[17]. Overall agreement between the models was reported by Rossini et al. to range from 78% to 87% in measurements. Furthermore, the study did not find any notable variations in the two models that could cause clinical impact [18, 19]. However, because the measurements in the first technique were taken using software rather than Vernier calipersand rulers in the second technique, the intra-observer variation with digital models was lower than with clay models. Abizadeh et al. and Costalos et al. found disagreement with the current analysis, citing a 0.14 mm significant difference between the models that was not clinically meaningful [20]. The difficulties in differentiating the same landmarks on the digital and plaster models, the inability to enlarge the digital models for better understanding, the amount of time that passes between the time the impression is made and the plaster is poured, the plaster preparation procedure, and the data scanning could all be contributing factors to the variations in the results across the studies. process, the digital software's display and algorithms, the examiner's experience in understanding the digital models, and the ease of using the software [21, 22].

There was no link found in the mean maxillary incisor inclination between the techniques measured for the plaster models and cephalogram, which were 126.86 ± 7.44 and 128.32 ± 7.03, respectively, in the current investigation. Most of theresearch has concluded that plaster models are preferable to lateral cephalograms. In comparison to measures of incisal angulations established using radiographic technology, Richmond et al. showed that measurements of dental casts acquired using the Reflex Metro graph coupled to a computer were more accurate, reliable, straightforward, and affordable [23]. In contrast, the lateral cephalogram approach for maxillary incisor angulation was highlighted by 10.46° when using the protractor method on dental casts. The disadvantages of cephalograms were mentioned to include the use of ionizingradiation and mistakes in landmark registration when measuring the inclination using the occlusal plane as a reference, which the plaster model overcame. Further, the radiographic technique is associated with the superimposition of the apex of all six anterior teeth, leading to a lack of clarity regarding the apex of interest and providing less accuracy over the plaster models. Additionally, in diverse crown-root-angle patients, the line drawn from the tip of the incisor to the apex may not accurately reflect the incisor inclination [24].

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Nevertheless, the plaster models too have certain limitations wherein they use the occlusal plane (which is constantly changing during orthodontic treatment) as a reference over the skeletal plane used in cephalograms.

In the current investigation, using digital and plaster models, the mean mandibular incisor inclination was 60.20 ± 6.75 and 55.14 ± 7.55, respectively, with considerably low-strength linked data. These findings were consistent with Bell et al.'s findings, which showed no discernible difference between the measurement and landmark on the plaster and digital models. But because the digital models employed software for measuring while the clay models used a Vernier calliper and ruler, they did see less intra-observer variance with the digital models. A 1.58mm variation in measurements between these methods produced results that were comparable, trustworthy, and acceptable while also having no discernible clinical consequence. A significant risk of making mistakes when attempting to eliminate artefacts from digital models and errors due to merging the scans into a single image were noted.

High-level data indicates that digital models are equally reliable as traditional plaster models in terms of repeatability, accuracy, cost, and time savings, as well as the quantity of materials and storage space required. However, there is a learning curve for digital models to become familiar with the software; as a result, when more familiarity with the digital technology is gained, the measurement difference between digital and plaster models tends to reduce. Between 78% and 87% of 40 cases showed agreement between the two approaches, indicating that computer-aided digital models may effectively cure malocclusions in place of plaster models [25]. Costalos et al. provided indifferent data that showed a substantial divergence between the plaster and the digital model in the buccolingual inclination of the incisor, suggesting that there was no association. between them. It is important to note that the plaster models inherit certain limitations, thereby compromising their reliability. The reliability of these plaster models in cases of severe Wilson, open bites, canted occlusal planes, deep Spee, and malposed teeth is highly questionable.

In the current investigation, the mean mandibular incisor inclination for cephalograms and plaster models was 61.04 ± 6.15 and 55.14 ± 7.55, respectively, with measurements between the approaches showing a significant correlation. Studies published in the literature, however, demonstrated that crown angulation of mandibular incisors measured using a protractor and scale on dental cast models was 2.57° more accurate, valid, and superior to the lateral cephalogram technique. The differences in outcomes may be related to symphysis, the bony opposition at the mandibular angle, and cases with a deep Spee curve. Conflicting results were also published by Richmond et al., who claimed that measurements taken of dental casts using a computer and the Reflex Metro graph were more accurate and realistic than measurements of incisal angulations. using radiographic technique. The tooth inclination protractor method recorded mandibular crown inclination 19° less than mandibular incisor to occlusal plane and stated dental plaster model measurement using protractor and scale to be better than the lateral cephalogram method [26]. Considerable attention should be given to the fact that the angle at which the caliper ends are placed on the plaster model and the plane at which the observations are carried out by the examiner may contribute to the inaccuracies reported with the plaster model technique.

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The body of evidence demonstrating the superiority of digital models over plaster models and cephalograms is increasing over time. The Ortho CAD helps to determine a model's correctness by helping to get several scans of the model in thin slices. Furthermore, the limitations of storage space—which can require up to 17 m3 for a thousand patients—are removed by the digital models. The advantage of digital models is the ability to transport images to any location in the world for quick referrals or consultations, as well as fast access to 3D data without requiring the retrieval of plaster models [27]. To ensure that the data is not destroyed, digital models need to be backed up digitally and protected with a password and antivirus software. A further problem with the digital models is that they need to be properly oriented. digital software to view the images and mark the landmarks on the software by rotating the models.

There are several restrictions on the study. Initially, there was a dearth of information comparing digital models and cephalograms with the current study because it was the first to compare all three techniques. It is advised that future research compare digital models and cephalograms for measuring incisor inclination. Further research on the treatment outcomes with these techniques used in treatment planning can be planned, even though the present study concentrated on using different techniques for incisor inclination measurements. If treatment plans made with computer-based models differed significantly from those made with plaster models and cephalogram models, that would be the true test of clinical relevance.

6.Conclusion

The study found a significant correlation between maxillary incisor inclinations recorded using plaster models and digital models, but showed variation in measurements made using digital models and cephalograms. In the case of mandibular incisor measurements, both plaster and digital models showed comparable results, suggesting digital models should be used as a replacement.

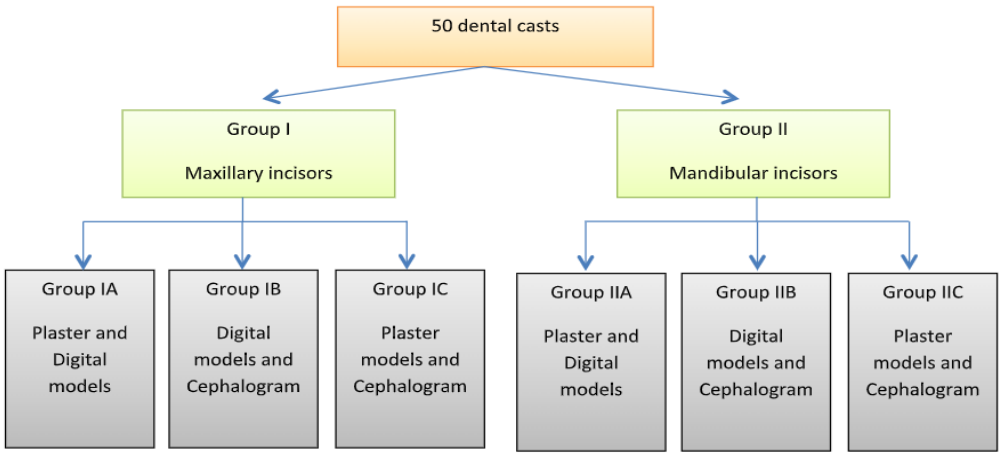

Figure 1- A flow diagram representing the group categorization as per the comparisons made

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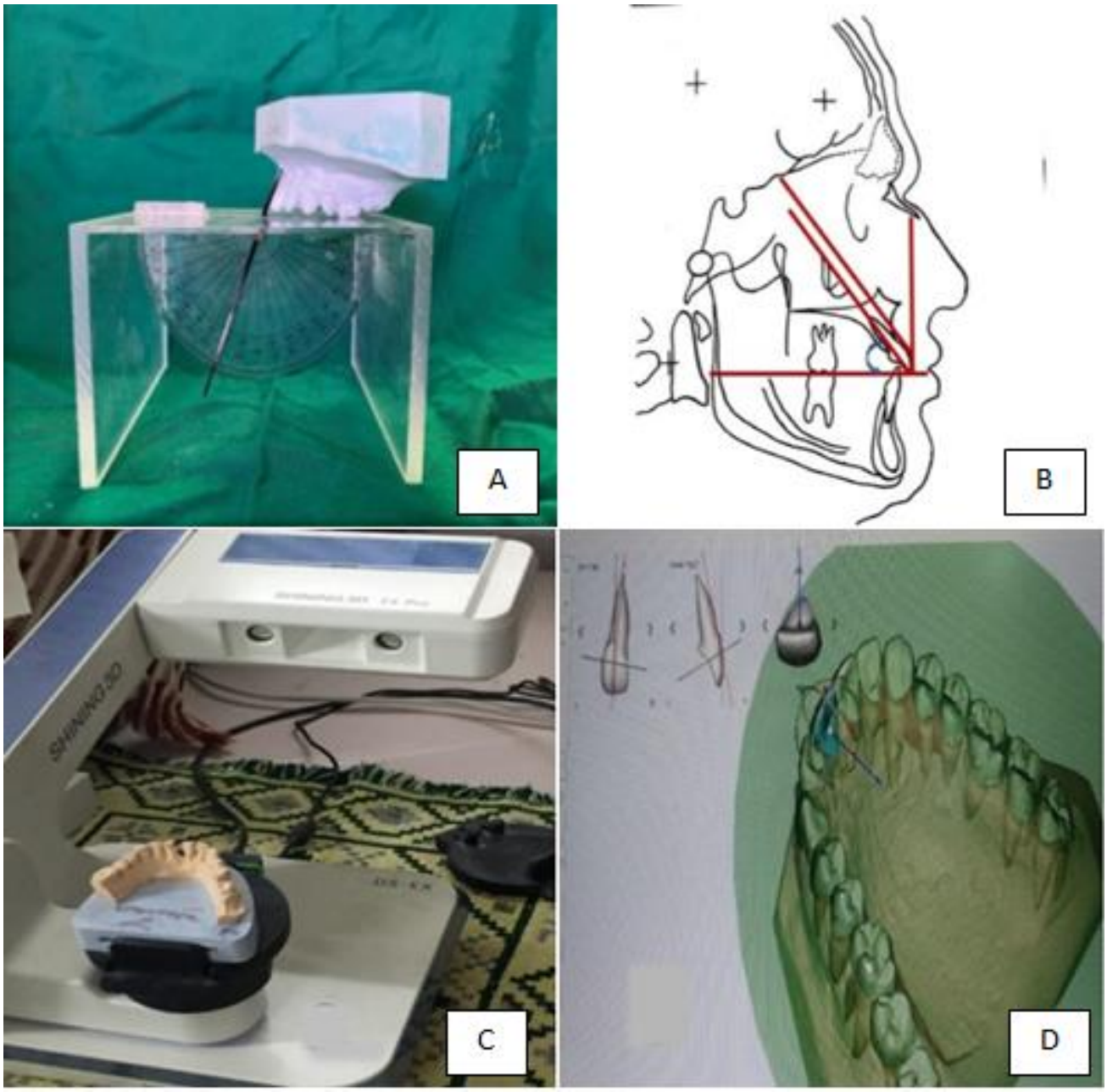

Figure 2- The figure representing the three technique used for incisor inclination measurement; (A): TIP instrument with horizontal plane, a conveyer, protractor and stainless-steel wire for contact with the labial surface of the tooth crown; (B): Lateral cephalogram with horizontal line as occlusal plane, 1st line demonstrating long axis of teeth, 2nd line demonstrating the facial axis point of teeth, and 3rd line demonstrating the perpendicular distance from occlusal line; (C): Shining 3D scanning machine used for scanning the dental models; (D): Maestro 3D software for measuring incisor inclination

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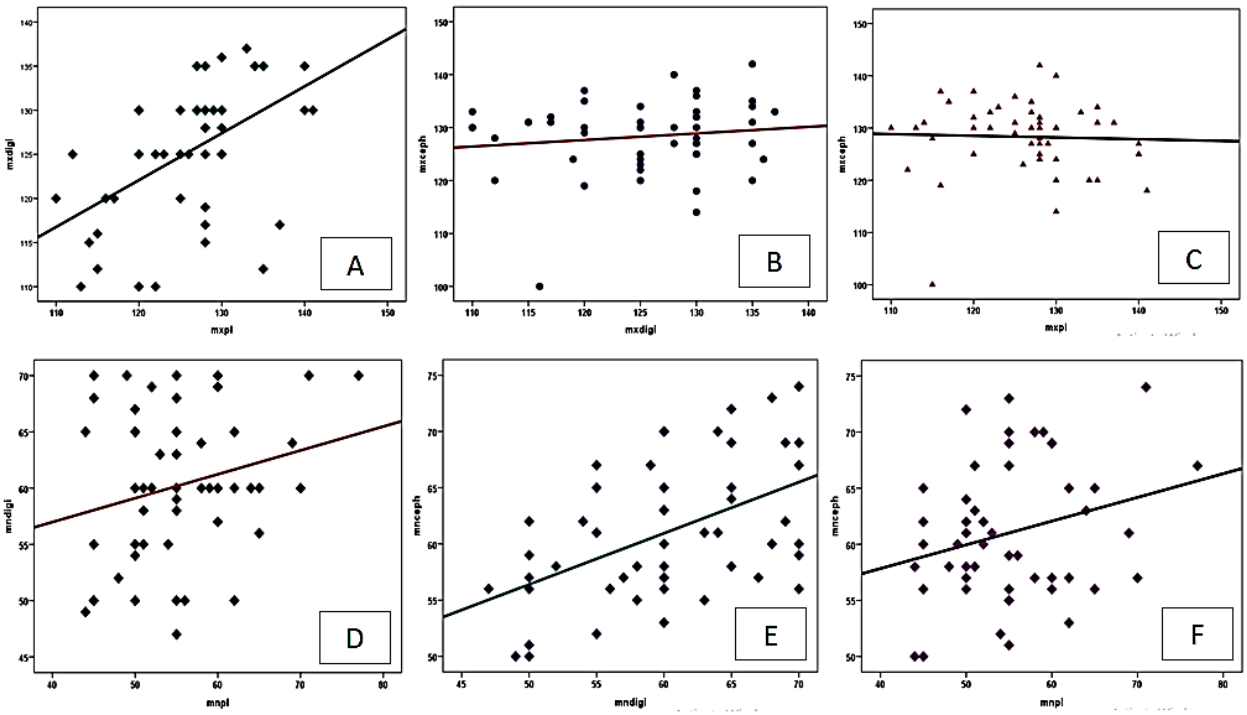

Figure 3- Figure representing correlation between the techniques for maxillary (A,B,C) and mandibular (D,E,F) incisor inclination; A,D: correlation between plaster model (x-axis) and digital model (y-axis); B,E: correlation between digital model (x-axis) and cephalogram model (y-axis); C,F: correlation between plaster model (x-axis) and cephalogram model (y-axis)

Table 1- Mean incisor inclination and correlation between the measurement techniques

Incisor	**Measurement techniques**	**Incisor inclination (mean ± standard deviation)**	**Intra-class correlation (95% Confidence Interval)**	**Significance (p)**
Maxillary incisors	Plaster model	126.06 ± 7.44	0.686 (0.446, 0.822)	<0.0001*
	Digital model	125.30 ± 7.58		
	Digital Model	125.30 ± 7.58	0.235 (-0.348, 0.566)	0.176
	Cephalogram model	128.32 ± 7.03		
	Plaster model	126.06 ± 7.44	-0.072 (-0.888, 0.392)	0.595

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	Cephalogram model	128.32 ± 7.03		
Mandibular incisors	Plaster model	55.14 ± 7.55	0.382 (-0.089, 0.649)	0.048*
	Digital model	60.20 ± 6.75		
	Digital Model	60.20 ± 6.75	0.664 (0.408, 0.809)	<0.0001*
	Cephalogram model	61.04 ± 6.15		
	Plaster model	55.14 ± 7.55	0.405 (-0.048, 0.662)	0.036*
	Cephalogram model	61.04 ± 6.15		

**Significance at p<0.05*

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