ACCURACY OF THE TOOTH INCLINATION PROTRACTOR TO MEASURE MAXILLARY INCISOR CROWN INCLINATION IN A SAMPLE POPULATION OF PESHAWAR

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ABSTRACT

Objective: The aim of this study was to determine the accuracy of measurements of incisor inclination by tooth inclination protractor (TIP) versus lateral cephalogram.

Methods: Pre-treatment dental casts and lateral cephalograms of 200 patients were selected from the Orthodontics Department of Khyber College of Dentistry, Peshawar in this cross-sectional study. Maxillary incisor inclination was measured on the dental casts using the custom-made TIP and on the lateral cephalograms. Correlation coefficients (*r*) were calculated. A paired t test was applied to find the mean difference between the incisor inclinations calculated by the two methods. P value ≤0.05 was considered significant.

Results: Dental casts and lateral cephalograms of 149 female and 51 male patients were used, with mean age of 17.91 ± 5.07 years. The mean labiolingual inclination of maxillary central incisor was 18.31 ± 8.17° on the dental casts, measured with TIP, and 21.24 ± 10.34° on the lateral cephalogram (angle between facial tangent line of maxillary central incisor and occlusal plane perpendicular). There was a moderate correlation between the two methods (r=0.658). Paired t-test showed a difference of 2.94 ± 7.91° between two methods, which was insignificant.

Conclusion: TIP is comparable with lateral cephalogram for measuring maxillary incisor proclination.

Keywords: Cephalometry, Incisor, Radiology

INTRODUCTION

One of the aspects of orthodontic treatment planning is incisors inclination, which helps in deciding the treatment path - whether or not to include extractions of teeth to avoid/correct protruding or retruding incisors. During the initial stages of orthodontics treatment, the incisors may procline more than desired. Again, whether extractions are required to correct this, or simple enamel stripping may be sufficient, that is decided by finding the incisor inclination.

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The correct inclination of the anterior teeth helps to achieve an attractive facial appearance.[1] Facial appearance influences the self-esteem of a person.[2] Hence, it is important to check the incisor inclinations during orthodontic treatment. Orthodontists universally use a lateral cephalogram for this purpose. Different analyses for cephalograms are available that use different landmarks, reference lines and angles to find out how protrusive or retrusive the incisors are from a given reference plane.[1,3,4] How protrusive/retrusive the incisors are determines how forward or backwards they need to be moved to achieve an esthetic result, and the measures taken to achieve those movements (extractions of teeth, enamel stripping, space creation). But cephalograms require exposure to radiation, which is known to have negative effects on both hard and soft-tissues, hence, it can't be repeated frequently.[5,6] It's prone to reproducibility errors[7] due to superimposition of bilateral structures, or due to reduced image density or sharpness which causes errors in identification of landmarks.[8] Magnification errors - if not addressed - lead to incorrect measurements. Linear measurements and

angular measurement between the horizontal planes are usually affected by head rotation.[9] MRI has been proposed as a reliable substitute for lateral cephalograms,[10] as it lacks the radiation exposure, but it also suffers from the same drawbacks - superimposition of bilateral structures, reduced image quality leading to errors in landmark identification and magnification errors.[11] These drawbacks of the two imaging methods may lead to under- or over-estimation of incisor inclination.

Apart from a lateral cephalogram, although very rarely used, dental casts can also find the incisor inclination. They are replicas of the oral cavity and record the dentition in 3D which is useful for studying arch length, and depth, and arch length to tooth size discrepancies. Yet, few studies have been conducted on casts to assess the inclination of incisors and molars. Incisor inclination is a measure of the angle between a facial surface tangent line of incisors in the middle of clinical crowns (facial axis point / FA point) and a line perpendicular to occlusal plane. It is a determinant of the esthetic position of facial surfaces of incisors. In 1998, Richmond developed the Tooth Inclination Protractor (TIP) as a simple and reliable method for measuring incisor inclination extra-orally using dental casts.[12] Ghahferokhi et al. constructed a disposable intra-oral TIP and compared it to the readings on a lateral cephalogram. The both found that TIP underscored readings on a radiograph.[13] These studies compared the inclination of the crown of a tooth to a reference plane using TIP, to the inclination of the entire tooth (crown and root) to a reference plane using a cephalogram. This may lead to unreliable results as the crown-root angle (collum angle), which may range from 5.12 ± 3.78 to 15.02 ± 7.99 in a Pakistani population, causes a discrepancy between the angle of the crown only, and the angle of the entire tooth (from the incisal edge to the root apex) to a reference plane.[14]

No local studies have been conducted to measure the accuracy of this device. We aimed to use the same landmarks and reference planes for finding the incisor inclination using a Tooth Inclination Protractor and a lateral cephalogram in a sample population of Peshawar, and compare the measurements obtained by the two methods.

MATERIAL AND METHODS

This cross-sectional study was conducted in Orthodontics Department of Khyber College of Dentistry, Peshawar, after obtaining ethical approval from the hospital's Ethical Committee in November 2020 (Letter No: 21/ADR/KCD). Permission from the department for use of patient records was also taken. The study was carried out from March 2022 to March 2023.

By using OpenEpi, taking the inclination (degrees) of the left central incisor as a parameter, the difference in cephalometrics of 8.6 ± 4.4 and 6.7 ± 6.0 using the two methods, the calculated sample size was 400, with 200 in each group, while keeping 95% confidence interval and 95% power.[15] of A total of 200 lateral cephalograms and 200 casts were used, using non-probability consecutive sampling. Records of those patients were included in the study who had casts without bubbles, voids, and broken teeth & who had lateral cephalograms in which the anatomic structures and landmarks required for our study could be readily seen due to the difference in the degree of blackening of the adjacent structures (high contrast). The casts and cephalograms were individually assessed for the above criteria by the researchers. The patients had no congenitally missing or extracted teeth, except the third molars, and minimal crowding and spacing. Records of patients with craniofacial syndromes, cleft lip and palate, previous orthodontic treatment, fractured teeth and/or abnormal morphology of incisors (i.e., dilacerations, fusion, germination etc.) were excluded because these conditions are usually associated with abnormal/altered morphology and inclination of teeth, which will act like outliers in our study and skew the results of our data analysis.

Custom-made TIP was used to record maxillary central incisor inclination on dental casts. The device consisted of a flat platform with a 180^0 protractor attached on its undersurface. The platform had a perforation through which a needle passed. The upper end of the needle was to rest against the tooth on a dental cast, whereas the lower end was rested against the protractor to give readings. These readings reflected the inclination of labial the surface of the teeth to the occlusal plane. (Figure 1)

Figure 1: TIP with a dental cast mounted, ready for measurements to be taken.

Dental cast was positioned on the inclinometer such that first molars contacted the platform. The needle was positioned such that it rested against the incisor's labial surface at the maximum convexity. The inclination was then recorded on the graduated scale of the protractor.

Lateral cephalograms were manually traced by a single examiner. A line tangent to the maximum convexity on facial surface of the most prominent incisor was drawn. Maxillary incisor inclination was then defined as the angle between the tangent line and occlusal plane perpendicular (Figure 2). Reliability of measurements was assured by re-measuring readings from 20 casts and cephalograms by the same investigator after 2 weeks. It was measured using the Intra-class Correlation Coefficient, which was found to be 0.998 for lateral cephalograms; and 0.997 for dental casts, which is considered excellent reliability. (Table 1)

Table 1: Results of Reliability of Measurements using the Intraclass Correlation Coefficient

Method	**N**	**Mean labiolingual incisors inclination (degrees)**		**Correlation coefficient**
		1st reading	**2nd reading**	
Lateral Cephalogram	20	20.04±8.78	20.12±8.75	0.998
Dental Cast	20	19.05±7.29	18.92±7.31	0.997

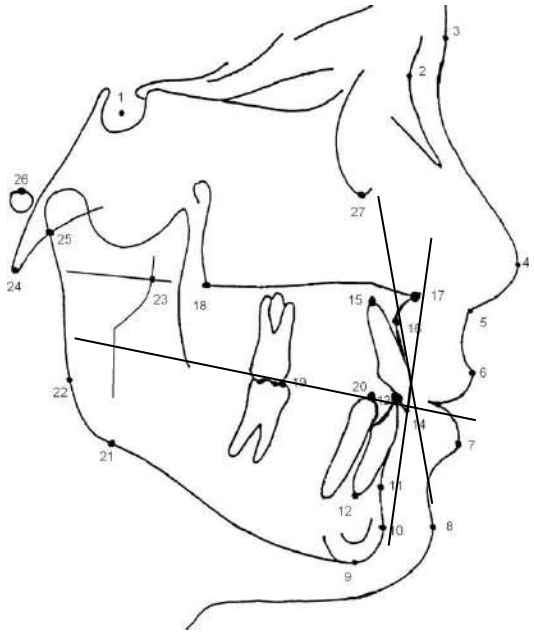

Figure 2. Measurement of Incisor inclination (Angle) on lateral cephalogram. Angle between Facial tangent line to maxillary central incisor and occlusal plane perpendicular.

Data was analyzed in SPSS 20. Mean and standard deviation (SD) were calculated for the numerical variables of age, incisor inclination on dental cast and on lateral cephalograms.

Pearson's correlation test was used to find the correlation between the measurements recorded with the tooth inclination protractor and lateral cephalogram.

The comparison of the two methodologies was then assessed with Paired t-tests.

RESULTS

Data from 200 lateral cephalograms and 200 dental casts was obtained from records of 149 (75.4%) female and 51 (25.5%) male patients. The mean age of the sample was 17.91 years ± 5.07, with an age range from 13 to 35 years. The mean age for females was 17.93 years ± 4.02, whereas for males it was 19.25 years ± 3.08.

The mean inclination of maxillary central incisor was 21.24 ± 10.34° on the lateral cephalogram, and 18.31 ± 8.16° on the dental cast. A moderate correlation (r=0.658) was found between the two measurements (Table 2).

Table 2: Pearson's correlation test for the two methods of measuring maxillary incisor inclination. (n=400)

Method	n	Mean labiolingual incisor inclination	SD	Minimum (Degrees)	Maximum (Degrees)	Correlation coefficient (r)
Lateral cephalogram	200	21.24°	10.34	0.5	38	0.658
Dental Cast	200	18.30°	8.15	-1	32	

The difference in labiolingual incisor inclination recorded with lateral cephalograms (21.24 ± 10.34) and dental casts (18.30 ± 8.15) was insignificant (p=0.239). Hence the two methods can be used interchangeably in a clinical setup.

DISCUSSION

Errors are known to occur in measurements recorded by a lateral cephalogram.[16] It usually records only the most prominent incisor. Superimposition and/or blurring of anterior teeth can lead to significant errors in

measurements as the incisal edges and root apices become blurred, making the operator guess the actual position of these landmarks. These guesses may or may not coincide with the actual position of that landmark and are not reproducible.

When using the radiographic technique, drawing a line between the incisor tip and the root apex will only reflect the actual incisor inclination to a reference plane when the angle of the crown to the root is 0°, which it is not in a Pakistani population.[14] A clinical method for measuring incisor inclination must be based upon the crown of a tooth, as it is the part which is visible in the oral cavity. The labial surface of a tooth is easiest to visualize. TIP can be used to clinically record the individual inclinations of all teeth,[15] from incisors to molars, enabling an appraisal of proclined or retroclined teeth, and even for estimation of root inclination.[17]

In one of the earliest studies conducted on TIP, Richmond et al. found that TIP consistently underscored the maxillary incisor inclination compared to the inclination recorded by the lateral cephalogram, by an average of 10.46° ± 4.56.[12] A correlation coefficient of 0.77 was found between the two methods. In our study, a smaller and insignificant difference was found between the two measurements (mean: 2.91° ± 7.91), although the correlation coefficient was comparable (r=0.658). The difference in the results of the two studies might be because both studies used different radiographic angles to describe the incisor inclination. We used the angle between facial surface tangent and occlusal plane perpendicular when measuring incisor inclination on the cephalograms and TIP, and hence, the difference between the two measurements was smaller. Whereas Richmond et al. used the angle between the long-axis of the incisor (from incisal edge to root apex) and occlusal plane perpendicular to measure incisor inclination on the lateral cephalogram, and used the angle between facial surface tangent and occlusal plane perpendicular when measuring incisor inclination with TIP, hence, it is not surprising that the difference between the two methods was greater.

In Ghahferokhi et al.'s study, maxillary incisor crown inclination to maxillary plane measured on x-rays was approximately 20° greater than the values recorded with extra-oral and intra-oral tooth inclination protractors used in their study.[13] This difference was because of the different incisor inclination angles used. On the radiograph, they used the inclination of central incisor long axis with occlusal plane perpendicular. While on the dental casts, the corresponding variable was defined as a line tangent to facial surface of the crown of central incisor and occlusal plane perpendicular. In our study, we used the facial tangent line on both lateral cephalogram and on the dental cast. Therefore, the difference between the two measurements is much less than that in Ghahferokhi et al.'s study.

In Shah et al.'s study, upper and lower incisors inclination with the jig were precise within a 10° range of the cephalometric value in 96% cases, and to 6° in 76% cases.[18] The mean differences between the cephalometric readings and jig measurements for upper incisor inclination was 0.8° ± 5.3 (Range: -8° to 14.5°). In our study, a relative greater difference was found. The difference in the results might be due to differences in the inclinometer design of the two studies. Shah et al. used a modified vernier caliper. One end of the caliper had a platform with a notch on it. The incisal edge of a tooth would fit into this notch. Instead of the length of the needle touching the labial surface of the tooth, as in our study, only the tip of the needle would perpendicularly contact the labial surface. This needle could be moved toward or away from the tooth, moving the dial.

As manual hand tracings of cephalograms continue to be replaced by 3D softwares,[19,20] a study by Nouri et al. compared measurements obtained by TIP to those obtained by a 3D software.[15] They found a strong correlation between the two methods (r=0.91), which is higher than that of our study which used manual hand tracing (r=0.658). Unlike in manual hand tracings, the contrast and sharpness of the radiographs can be adjusted in 3D softwares to give clearer images, and hence, they're more likely to give more accurate and reproducible readings compared to the manual method. This may be why the correlation between TIP and 3D softwares is higher than with TIP and manual hand tracing.

The difference in measurements recorded with TIP and lateral cephalograms in the different studies may be because of the differences between crown and root inclinations for the incisors. TIP records incisor inclination with respect to the actual occlusal plane of a patient. While, on lateral cephalograms, due to superimposition of the right and left molars, a perceived occlusal plane is constructed. This could explain the systematic difference between the means of incisor inclinations obtained by using a TIP or lateral cephalogram. Most studies used a small sample size of around 50 participants, whereas we used 200 participants. A larger sample size is more likely to produce estimates of the treatment effect that

more closely approximate the parameters for that population.[21]

TIP is a simple, inexpensive noninvasive, and reliable method to assess incisor inclination on dental casts. It can be used for continuously recording changes in incisor inclination during treatment, which is unjustifiable and unethical with a lateral cephalogram due to radiation exposure.[22] It can be employed as a tool in research for estimating incisor correction.

CONCLUSION

TIP consistently underscored the maxillary incisor inclination by an average of 2.94 ± 7.91°, compared to the lateral cephalogram, but the difference was insignificant. Hence, TIP is clinically acceptable for measuring maxillary incisor inclination during orthodontic treatment. As it does not require exposure to radiation, it is cost-effective and saves time by eliminating the trip to a radiologist for a lateral cephalogram. The device can be made in the hospital and be readily available for use when needed.

DECLETRATIONS

Authors Contributions:

Muhammad Asim: Design conception and supervision

Muhammad Saood: Literature search, data collection

Muhammad Aizaz Khan: Sample collection, data analysis

Umara Khalid: Data interpretation and reviewing of manuscript.

Zubair Wali Muhammad: Literature searches

Mashal Afridi: Final reviewing and editing of the manuscript.

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