ORIGINAL RESEARCH

Determination of Labiopalatal Angulation of Maxillary Anterior Teeth Using Manual Method and Digital Methods: A Comparative Study

Ashika Bachira Kashi[1], Subhash Sonkesriya[2], Ashley Thomas[3], Prasanth Prathapan Santhakumari[4], Rajat Mohanty[5], Abhilash Abdul Iatheef[6], Shashidhara Hebbal Shadaksharappa[7]

Abstract

Aim: The aim of the present study was to evaluate labiopalatal angulation of maxillary anterior teeth using Custom-made jig, Profile projector, and ImageJ computer software methods.

Materials and methods: The subjects for this study were selected in the age-group of 20–30 years having permanent dentition, including 2nd molars and bilateral Angle's class 1 molar and canine relationship. Recording the labiopalatal angulation in proximal view was carried out by using one manual method and two digital methods namely using Custom-made jig, Profile projector, and ImageJ computer software, respectively. Alginate impressions were made for the subjects, and the spatial relationship of the maxilla to the cranium was recorded using a facebow. The casts were mounted in a semi-adjustable articulator, and the articulated mounted casts with the mounting ring were transferred to the Custom-made jig, and angulations were measured in proximal view. Digital methods of measurement were recorded by using Profile projector and ImageJ computer software methods. Data were tabulated and statistically analyzed.

Results: In males, the mean labiopalatal angulation of maxillary right and left maxillary canines of Custom-made jig was 91.94 ± 1.47 and 91.70 ± 1.68, in Profile projector method 87.41 ± 3.75 and 87.58 ± 3.79, and in ImageJ computer software 84.23 ± 5.72 and 83.29 ± 6.74, respectively. In females, Custom-made jig was 91.82 ± 1.55 and 92.17 ± 1.84, in Profile projector method 86.70 ± 5.58 and 86.94 ± 5.57, and in ImageJ computer software 82.76 ± 6.34 and 83.05 ± 6.12, respectively. There was a very high statistically significant difference found between different methods.

Conclusion: In conclusion, the values obtained in the digital methods (i.e., both the Profile projector and ImageJ computer software) were more accurate than the manual method. However, the ImageJ computer software was most reliable in comparison with the values obtained in Profile projector.

Clinical significance: The labiopalatal angulation of anterior teeth will act as a guideline in re-establishing the correct angulations and the anatomic contours of the maxillary arch to achieve the desired esthetics that provide adequate lip support and to restore the required functions.

Keywords: Facial axis of clinical crown, Labiopalatal angulation, Profile projector, Reference planes.

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Introduction

Natural permanent teeth eruption and attaining their final positions is a natural and biological phenomenon. Natural maxillary and mandibular anterior teeth occupy a definite place and position in order to perform functions like swallowing, mastication, and speech. Their definite position and angulation with respect to the three different anatomic reference planes are the reasons for good esthetics and functions.[1]

Individual tooth is inclined labially or palatally and can be viewed clinically or with any other diagnostic aids like mounted diagnostic casts, photographs, etc., which affects the functions and esthetics.[2] The inclination or angulations of individual maxillary anterior tooth are determined, which favors the physiologic functions.[3]

The ideal positioning of maxillary anterior teeth is greatly influenced by the orientation of the occlusal plane. Thus, the optimal occlusal plane establishment is highly reliable on different anatomic reference planes such as Frankfurt Horizontal plane, Campers plane, etc.[4] The positioning of maxillary and mandibular anterior teeth at definite angles would help in providing correct anterior guidance (adequate overjet and overbite), thus playing an important role in protecting the posterior teeth from the protrusive and lateral stresses by their discluding effect to enhance long-term occlusal stability.[5]

[1]Department of Prosthodontics, Coorg Institute of Dental Sciences, Virajpet, Kodagu, Karnataka, India

[2]Department of Prosthodontics, Government College of Dentistry, Indore, Madhya Pradesh, India

[3]NMC Royal Hospital, Sharjah, United Arab Emirates

[4]Department of Orthodontics, Indira Gandhi Institute of Dental Sciences, Kothamangalam, Kerala, India

[5]Department of Oral and Maxillofacial Surgery, Kalinga Institute of Dental Sciences, KIIT Deemed to be University, Bhubaneswar, Odisha, India

[6]Department of Conservative Dentistry and Endodontics, Sri Sankara Dental College, Varkala, Thiruvananthapuram, Kerala, India

[7]Department of Prosthodontics, College of Dental Sciences, Davanagere, Karnataka, India

Corresponding Author: Ashika Bachira Kashi, Department of Prosthodontics, Coorg Institute of Dental Sciences, Virajpet, Kodagu, Karnataka, India, Phone: +91 9741669104, e-mail: drashikabk@gmail.com

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Anterior teeth angulations are traditionally assessed by lateral cephalometric radiographic analysis (two-dimensional radiographic techniques). However, lateral cephalometric radiograph-derived axial inclinations of the maxillary anterior teeth are more prone to digitizing errors. Moreover, three-dimensional (3D) software programs and 3D imaging (CBCT) have high reliability and accuracy for angular measurements. However, there is insufficient information regarding the labiopalatal angulation of maxillary anterior teeth in natural dentition in relation to different reference planes, which is required for rehabilitations of teeth at a definite angulation.[6] Hence, the present study was conducted to evaluate the labiopalatal angulation of maxillary anterior teeth on right and left sides between males and females in proximal view by manual method (Custom-made jig) and two digital methods (Profile projector and ImageJ computer software).

Materials and Methods

The present study was conducted in the Department of Prosthodontics, College of Dental Sciences, Davanagere, India, during the year of 2019–2020. Subjects with all six natural permanent maxillary right and left anterior teeth, bilaterally symmetrical face, complete permanent dentition in maxillary arch, including 2nd molar, angle's class I canine and molar relationship, competent lip contact, clinical crown height of the concerned teeth 7–10 mm, and subjects with overbite and overjet 2–4 mm were included in the present study.

Subjects with apparent loss of tooth structure in maxillary anterior region due to caries, cracks, fracture, and any wasting diseases affecting the teeth, severely rotated maxillary incisors, malformations, midline diastema, compromised facial symmetry, congenital or acquired facial deformity, who have undergone or undergoing any orthodontic treatment, systemically compromised patients such as Down's syndrome, ectodermal dysplasia, history of previous or current orthodontic treatment, severe malocclusion, any questionable periodontal pathology of concerned teeth, cleft lip or palate or those that have been treated for the same, and subjects with parafunctional habits were excluded from the study.

Sample-size Calculation

The subjects for this study were selected in the age-group of 20–30 years. The study was conducted among 34 subjects (17 males and 17 females) after being informed about the nature of investigation and obtaining consent from each subject.

The formula used for sample-size estimation: $n = Z2\sigma2/e2$, where n = sample size, Z = statistic value for confidence limit = 1.96, σ = standard deviation = 0.96, e = instrumental error = 0.32, $n = (1.96)2 \times (0.96)2/(0.32)2 = 34.33$, rounded to 34 subjects (to include equal number of males and females).

Recording the labiopalatal angulation in proximal view was carried out by using one manual method and two digital methods namely using Custom-made jig, Profile projector, and ImageJ computer software, respectively.

Manual Method

Preparation of Custom-made Jig

The Custom-made jig maintains the position of the mounted cast as oriented in Hanau Wide Vue articulator. It has a horizontal platform to which the mounted cast with the mounting ring can be attached using screw beneath the platform. The vertical arm that extends from one end of the platform has a frictional movement in the horizontal direction (i.e., right and left). The horizontal arm that was attached to the vertical arm has a frictional movement in vertical direction (i.e., upward and downward). The height of the horizontal arm above the platform can be adjusted using the screw on the vertical arm. A standard 180° plastic protractor was attached to the free end of the horizontal arm of the device, and the protractor can be rotated from one side of the arch to the other side. The protractor can measure accuracy of 0.5°. A movable pointer was attached over the middle of the protractor, which extends beyond the protractor on either side to achieve contact with the teeth. The whole assembly was movable on the platform from right side of the platform to the left side (Fig. 1).

Recording of Labiopalatal Angulation Using Custom-made jig in Proximal View

The mounted maxillary cast with mounting ring was removed from the semi-adjustable articulator (Hanau Wide Vue, Whip mix articulator). The maxillary cast with the mounting ring was mounted on the horizontal platform of the custom-made jig. A point was marked on the deepest portion of the cervical region on the labial surface and on the highest point on the incisal edge of the maxillary anterior teeth on the mounted cast. Then, the mesiodistal width of the maxillary anterior teeth was measured using a digital Vernier caliper (aerospace 0–150 mm, 0.01 mm resolution) and the midpoint was marked on the labial surface. All these points were joined using a lead pencil, dividing the labial surface of the anterior teeth into two halves. This long axis marked was the facial axis of clinical crown (FACC). The horizontal arm of the jig that is attached to the standard 180° protractor with the movable pointer was adjusted such that one end of the pointer was placed against the FACC line such that it was parallel and tangent to the FACC at the FA point. The other end of the pointer was rested against the graduated scale on the protractor. The reading on the graduated scale of the protractor reflects the labiopalatal angulation of the maxillary anterior teeth in the proximal view with respect to the horizontal plane (Fig. 2).

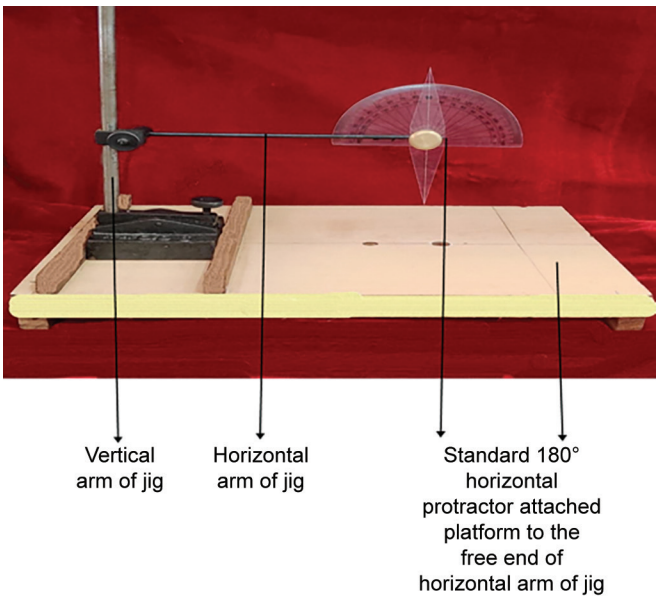

Fig. 1: Custom-made jig used in the present study

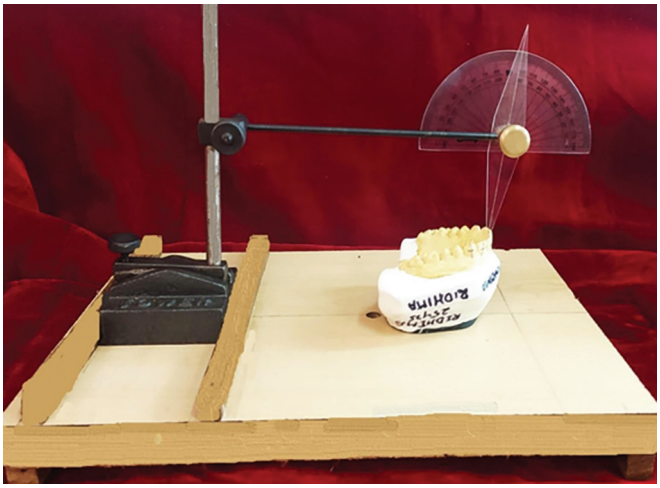

Fig. 2: Maxillary cast along with the mounting ring is mounted on the custom-made jig, and angle is measured in the proximal view

Digital Methods

Profile Projector (NIKON V-12A)

Recording the Labiopalatal Angulation Using Profile Projector in Proximal View

The articulated mounted cast was positioned on the stage with the help of a specimen (articulated mounted cast) holder. The sharpest image of the corresponding anterior teeth of the articulated mounted cast was focused on the digital protractor screen. The vertical line, which coordinates the *y*-axis, was oriented along the horizontal plane of the anterior teeth, which was taken as the reference by rotating the screen to the angular position 0 degrees such that the cross-lines (*x* axis and *y* axis) were at right angle (perpendicular) to each other. Then the horizontal line, which coordinates the *x*-axis, was oriented in such a way that the FACC line on the labial surface of the maxillary anterior teeth corresponded with the *x*-axis (horizontal line) of the digital protractor screen, and the angles were recorded. This procedure was repeated for the remaining teeth, and the angulations were recorded (Fig. 3).

ImageJ Computer Software

Recording the Labiopalatal Angulation Using ImageJ Computer Software in Proximal View

The articulated mounted casts were mounted on the horizontal platform of the Custom-made jig such that the horizontal arm of the jig is parallel to the mounting ring of the articulated mounted cast, which was considered as a reference for measurement. The camera-to-tooth distance was kept at 150 cm for all the images to eliminate image distortion and to ensure control of magnification. The articulated mounted casts were oriented so that the lens of the digital camera was parallel to the labial surfaces of the anterior teeth. Each of the standardized digital images of the articulated mounted casts in the proximal and incisal view was uploaded to the personal computer. By using the Angle Tool of the ImageJ computer software, the angulations of maxillary anterior teeth (central incisor, lateral incisor, and canine) on both the right and left sides were measured in proximal view and noted. All the subjects' casts underwent the three different modes of analysis and a single calibrated investigator was involved in the recording

Fig. 3: Profile projector (NikonV-12A) used in the present study

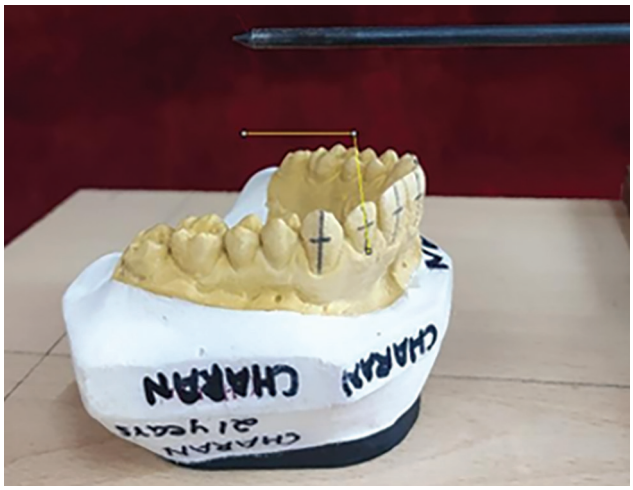

Fig. 4: ImageJ computer software for angle measurement in proximal view

of labiopalatal angulations of all methods. The results thus obtained were tabulated and were further subjected to statistical analysis (Fig. 4).

Statistical Analysis

The results were compiled in Microsoft Excel Sheet and transferred to IBM SPSS version 22.0 software. Statistical analysis was done using paired *T*-test, one-way ANOVA, and Tukey's post-hoc tests.

Results

The study was conducted among 34 subjects, i.e., 17 males and 17 females around the age-group of 20–30 years. In males, the mean labiopalatal angulation of maxillary right and left maxillary central incisors of Custom-made jig was 100.64 ± 3.85 and 99.94 ± 3.71, in Profile projector method 103.29 ± 3.90 and 102.41 ± 3.98, and in ImageJ computer software 101.23 ± 5.34 and 100.11 ± 4.94. In females, Custom-made jig was 98.11 ± 4.25 and 98.0 ± 4.78, in

Profile projector method 101.11 ± 3.73 and 101.47 ± 3.59, and in ImageJ computer software 98.52 ± 4.59 and 98.11 ± 4.38. There was a statistically significant difference in the labiopalatal angulation of maxillary left central incisors in females between manual method – custom-made jig and digital methods – Profile projector and ImageJ computer software as *p*-value is <0.05 (Table 1 and Fig. 5).

Table 2 and Fig. 6 depicts, in males, the mean labiopalatal angulation of maxillary right and left maxillary lateral incisors of Custom-made jig was 98.11 ± 4.12 and 97.94 ± 3.92, in Profile projector method 100.29 ± 3.49 and 100.05 ± 2.90, and in ImageJ computer software 98.52 ± 5.64 and 99.0 ± 5.01, respectively. In females, Custom-made jig was 96.70 ± 3.78 and 95.94 ± 4.22, in Profile projector method 98.23 ± 3.81 and 97.82 ± 4.21, and in ImageJ computer software 96.70 ± 5.25 and 96.64 ± 4.59, respectively. There was no statistically significant difference in the labiopalatal angulation of maxillary right and left lateral incisors in males and females between manual method – Custom-made jig and digital methods – Profile projector and ImageJ computer software.

In males, the mean labiopalatal angulation of maxillary right and left maxillary canines of Custom-made jig was 91.94 ± 1.47 and 91.70 ± 1.68, in Profile projector method 87.41 ± 3.75 and 87.58 ± 3.79, and in ImageJ computer software 84.23 ± 5.72 and 83.29 ± 6.74, respectively. In females, Custom-made jig was 91.82 ± 1.55 and 92.17 ± 1.84, in Profile projector method 86.70 ± 5.58 and 86.94 ± 5.57, and in ImageJ computer software 82.76 ± 6.34 and 83.05 ± 6.12, respectively. There was very high statistically significant difference in the labiopalatal angulation of maxillary right and left canines in both males and females between manual method – Custom-made jig and digital method – Profile projector and ImageJ computer software as *p* value is 0.0001 (Table 3 and Fig. 7).

The inference of the present study indicates that the values obtained with the ImageJ computer software were most reliable in comparison with the values obtained in Profile projector and Custom-made jig method.

Discussion

The proximal view of maxillary anterior teeth determines the anterior slope (labial inclination) slightly offset from the vertical. These inclinations are at a definite angulation with the respective anatomical planes. The ideal positioning of maxillary anterior teeth is greatly influenced by the orientation of the occlusal plane. Thus, the optimal occlusal plane establishment is highly reliable on different anatomic reference planes such as Frankfurt horizontal plane, Campers plane, etc. The Frankfurt horizontal plane is seldom used. This plane is defined by a line drawn from the lowest point on the inferior orbital margin (orbitale) to the most superior point of the outline of the external auditory meatus (porion), directly above its center. It has been stated as one of the best-known reference planes.[7]

When the natural teeth are lost, there is loss of both function and esthetics. Dental esthetics is an important factor contributing to facial esthetics. The maxillary anterior teeth, i.e., the central incisor, lateral incisor, and canines are anatomically positioned in the esthetic zone and are the first to be seen when an individual speaks or smiles. Placing the anterior teeth in harmony with functional activity involves placing the teeth in an anterioposterior and mediolateral position in harmony with the action of lips and the tongue.[4,8]

In proximal view, the labiopalatal angulations of maxillary anterior teeth between males and females were found to have no statistically significant difference. This is in accordance with the data published by Andrews[9] and Okeson.[10] When comparing the right and left sides, no statistically significant difference was seen suggesting bilateral symmetry on both sides. This is in accordance with the data published by Verma et al.[11]

In the proximal view, the labiopalatal angulation obtained via three methods (manual method – Custom-made jig and digital method – Profile projector and ImageJ computer software) more or less followed a pattern similar to Andrew's observations. The maxillary central incisor, lateral incisor, and canine showed a

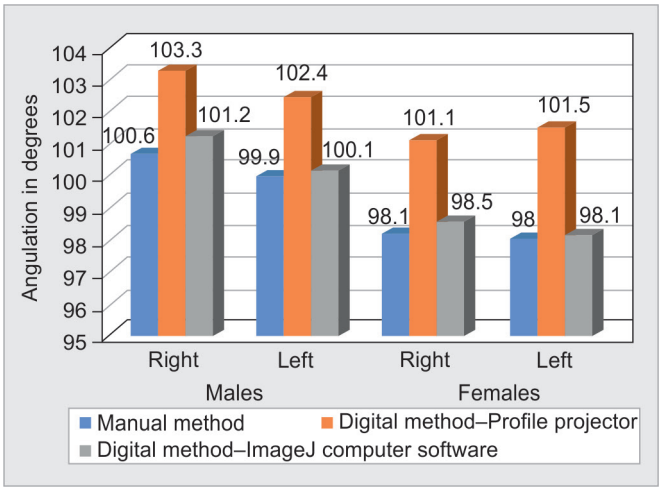

Fig. 5: Comparison of labiopalatal angulation of maxillary right and left maxillary central incisors in proximal view between manual and digital methods

Table 1: Comparison of labiopalatal angulation of maxillary right and left maxillary central incisors in proximal view between different methods

	Males		*Females*	
	Right	*Left*	*Right*	*Left*
Methods	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*
Manual method – Custom-made jig	100.64 ± 3.85	99.94 ± 3.71	98.11 ± 4.25	98.0 ± 4.78
Digital method – Profile projector	103.29 ± 3.90	102.41 ± 3.98	101.11 ± 3.73	101.47 ± 3.59
Digital method – ImageJ computer software	101.23 ± 5.34	100.11 ± 4.94	98.52 ± 4.59	98.11 ± 4.38
F value	1.680	1.788	2.534	3.601
p-value	0.197 NS	0.178 NS	0.090 NS	0.035 S

Table 2: Comparison of labiopalatal angulation of maxillary right and left maxillary lateral incisors in proximal view between different methods

	Males		*Females*	
	Right	*Left*	*Right*	*Left*
Methods	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*
Manual method – Custom-made jig	98.11 ± 4.12	97.94 ± 3.92	96.70 ± 3.78	95.94 ± 4.22
Digital method – Profile projector	100.29 ± 3.49	100.05 ± 2.90	98.23 ± 3.81	97.82 ± 4.21
Digital method – ImageJ computer software	98.52 ± 5.64	99.0 ± 5.01	96.70 ± 5.25	96.64 ± 4.59
F value	1.116	1.167	0.704	0.813
p-value	0.336 NS	0.320 NS	0.500 NS	0.449 NS

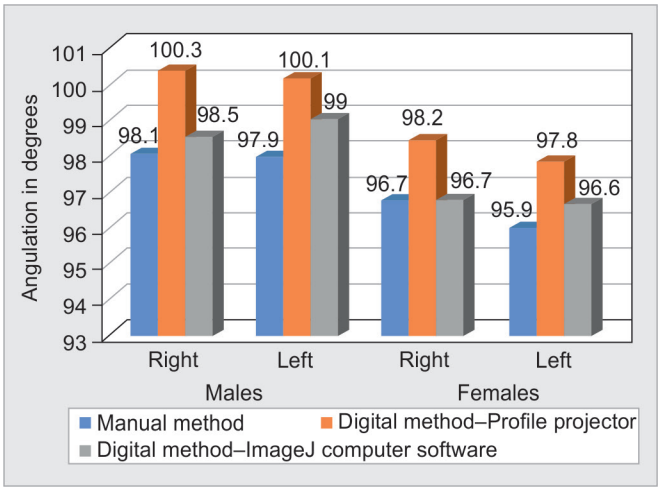

Fig. 6: Comparison of labiopalatal angulation of maxillary right and left maxillary lateral incisors in proximal view between manual and digital methods

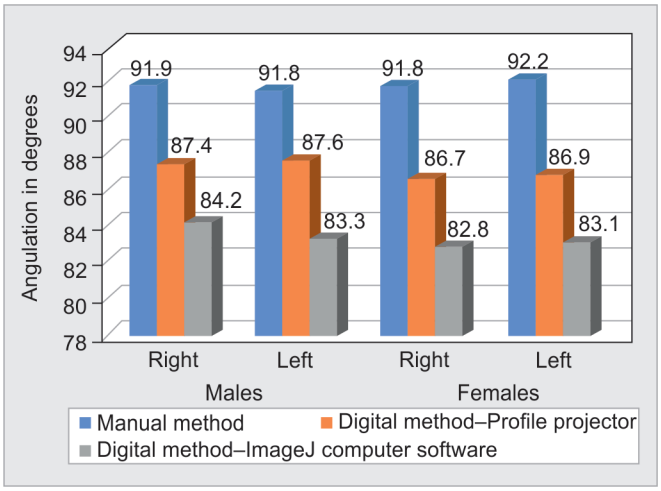

Fig. 7: Comparison of labiopalatal angulation of maxillary right and left maxillary canine in proximal view between manual and digital methods

Table 3: Comparison of labiopalatal angulation of maxillary right and left maxillary canines in proximal view between different methods

	Males		*Females*	
	Right	*Left*	*Right*	*Left*
Methods	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*	*Mean ± SD (in degrees)*
Manual method – Custom-made jig	91.94 ± 1.47	91.70 ± 1.68	91.82±1.55	92.17 ± 1.84
Digital method – Profile projector	87.41 ± 3.75	87.58 ± 3.79	86.70±5.58	86.94 ± 5.57
Digital method – ImageJ computer software	84.23 ± 5.72	83.29 ± 6.74	82.76±6.34	83.05 ± 6.12
F value	15.568	14.391	14.230	14.825
p-value	0.0001 VHS	0.0001 VHS	0.0001 VHS	0.0001 VHS

positive inclination in the manual method. This is in accordance with Solomon and Arunachalam.[12] According to Stananought,[13] the pattern followed by maxillary central incisor, lateral incisor, and canines was 8°, 12°, and perpendicular to the incisal plane in the proximal long axis. In the present study, 90° was taken as the vertical, and the maximum and minimum range of angulation of central incisor, lateral incisor, and canines were 94–106°, 92–106°, and 90–94°, respectively, such that they are at inclination of 4–16° for the central incisor, 2–16° for the lateral incisor, and almost perpendicular to the incisal plane for the canine. Hence, values in the present study also confirm with the values suggested by Stananought[13] for the arrangement of artificial teeth in proximal view.

In the digital method (Profile projector and ImageJ computer software), the maxillary central incisor and lateral incisor showed positive inclination, whereas the maxillary canine showed negative inclination. This indicates the crowns of maxillary canines are more

upright and vertical to the incisal horizontal plane when compared with the maxillary central incisor and lateral incisor. Negative inclination values of canines obtained with ImageJ computer software are nearly close to the Andrews values than the values obtained with the Profile projector. This is in accordance with the data published by Kannabiran et al.,[1] Verma et al.,[11] Fukagawa et al.,[14] and Sebata.[15]

However, there was a difference of 3–5° between the values obtained in the present study and the values suggested by Lawrence F Andrews. This difference depicts the possibility of racial and ethnic factors contributing to the difference in labiopalatal angulations in the proximal view. This is in accordance with the data published by Kannabiran et al.,[1] Verma et al.,[11] and Sheetal Kamble.[16]

Overall, since the standard deviations of the measurements for all teeth were greater than the differences between the measurements made with the three methods (Custom-made jig, Profile projector, and ImageJ computer software) and were also greater than the reliability of each technique alone, it seems that all three methods have clinically acceptable accuracy for measuring the labiopalatal angulations of maxillary anterior teeth in the proximal view.

The labiopalatal angulations, as obtained through this study and the values suggested by various authors, can serve as a guideline in the arrangement of teeth in completely edentulous and partially edentulous conditions, wax pattern fabrication, implant prosthesis designing, and cases with extensive attrition of teeth that require full-mouth rehabilitation, to achieve the desired esthetics, provide adequate lip support, and to restore the required functions.

Since the study was conducted in a limited number of subjects with class I condition, further study has to be conducted in a large number of subjects and in class II and class III conditions for the rehabilitation of completely and partially edentulous patients with the class II and class III conditions for more beneficial scientific results.

Conclusion

The present study concluded that the values obtained in the digital methods (i.e., both the Profile projector and ImageJ computer software) were more accurate than the manual method. However, the values obtained with the ImageJ computer software were most reliable in comparison with the values obtained in Profile projector.

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