Agreement of Dental Students in the Detection of Normal Landmarks When Comparing Digital Lateral Cephalograms and Three-Dimensional Cone Beam Computed Tomography Images

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Abstract

Background: Proper defining of normal landmarks in lateral cephalograms is important for establishing proper orthodontic treatment plan.

Objectives: To evaluate the agreement of dental students to identify normal landmarks (NLs) in digital lateral cephalograms and cone beam computed tomography (CBCT) images.

Patients and Methods: In this study, lateral cephalograms and CBCT images of 11 orthodontic patients were selected. Three fourth-year dental students were asked to identify 19 NLs after calibrating digital lateral cephalograms and 3D CBCT images. Then, the distances of each landmark from the superior and anterior edges of the images were measured for each observer.

Results: The observers' errors fell within a range of -1.03 to 2.74 in two-dimensional cephalometry and a range of -0.88 to 2.31 in 3D CBCT, showing a 95% limit of agreement. According to the intraclass correlation coefficient (ICC) comparison made by our student observers, only 5% of interobserver assessment in CBCT and 20% in lateral cephalometry showed poor reliability. These same observers showed more agreement when identifying NLs on soft tissue as compared to hard tissue structures and also in detecting NLs located in the midsagittal region rather than on lateral sides in both modalities. Their differences in agreement in detecting midsagittal NLs rather than on lateral sides were statistically significant ($P = 0.0001$).

Conclusions: The training of cephalometric tracing in orthodontic course based on 3D skull models and imaginary methods was deemed successful in increasing the ability of dental students to determine the precise location of NLs, even on CBCT images.

Keywords: Anatomic Landmark, Cephalometry, Cone Beam Computed Tomography

1. Background

Since introducing the first standardized cephalograms, cephalometric analysis has become a necessity in designing orthodontic treatment. Several factors that influence the detection and tracing of normal landmarks on lateral cephalograms are image quality, accuracy and reproducibility. In cephalometric analysis, errors may occur that are caused by the geometry of the X-ray beam, overlapping anatomical structures, the different magnification of bilateral structures and patient head position (1-3). Projectional magnification and distortion could lead to variations in orthodontic and surgical treatment planning (4). Many anatomical landmarks used in cephalometric analysis are located in the midsagittal plane and are not prone to the errors of structural superimposition, but other paramedial structures become distorted because of

their locations in different depths (1).

New technological advances in craniofacial imaging such as CBCT improve the ability of identifying anatomical landmarks by providing the facility of reconstructing three-dimensional (3D) images. It seems that CBCT technology allows us to overcome the inherent errors of two-dimensional (2D) cephalograms and to further improve the identification of cephalometric landmarks (5). As a result, by using CBCT images, the accuracy and reliability of observers in identifying normal landmarks increase (6-8). The most important advantages of using CBCT lateral cephalograms are the ability to reposition or to realign the head orientation digitally when the patient's head position is not correct and to generate separate images of both left and right sides which are used to properly assess facial asymmetry (5). Primary reconstruction of the right and

left sides in CBCT prevents projectional magnification that is seen in conventional cephalograms (9).

Replacement of conventional radiographs with 3D images may be an unavoidable or predictable trend especially in complicated skeletal deformities. In order for the orthodontic community to accept this inevitable transition from 2D to 3D analysis, achieving harmony of CBCT-derived analysis with the analysis of the existing database on lateral cephalograms is necessary (8, 10). Various studies have been performed to evaluate normal landmarks on CBCT-derived cephalograms (11, 12). In addition, the precision and accuracy of measurements made via CBCT images have been studied by several investigators (11, 13-15). It has been reported that measurements on CBCT-derived cephalograms did not clinically differ from those on conventional cephalograms in vivo or in vitro (11, 13).

Reliability of 3D analysis of anatomical landmarks and the feasibility of correctly identifying anatomical features in their respective sites has been studied, but not fully accepted yet (16, 17).

Inconsistency in properly defining landmarks is one of the major sources of error made when attempting to obtain reliable and accurate cephalometric measurements. In addition to imaging quality, many other variables potentially influence landmark identification errors, including the location and characteristics of individual landmarks, the experience of the observer and the information available regarding the patient's personal/treatment history (i.e. age, sex, metallic restorations in the mouth and facial asymmetry). However, the many variables that potentially affect landmark identification errors in CBCT cephalograms are not completely known yet (12).

Cephalometric landmark tracing-based teaching on 2D cephalometric radiographs is important in orthodontic courses. The concerns about transitioning from using 2D images to 3D scans can be reduced by knowing the degree to which 2D training on landmark identification may be generalized to achieving accurate landmark identification in 3D images as most oral specialists, especially orthodontists, are more familiar with identifying normal landmarks in 2D images. As a result, it is thought not to be that easy to adapt dental practitioners to using 3D imaginary methods.

2. Objectives

This study was designed to investigate the effect of routine orthodontic training course during dental education on the degree of agreement that exists among dental students when making an assessment of normal landmarks in 3D views of CBCT images. We want to confirm that we only focused on the effects of 2D orthodontic training on perception of 3D views of CBCT modality.

3. Patients and Methods

In this descriptive-analytical study, we compared 11 randomly selected digital lateral cephalograms with their corresponding CBCT images obtained from a private dental imaging clinic. The selected orthodontic patients did not have syndromal or craniofacial diseases. High quality lateral cephalometric images were available for these patients who also needed CBCT for various reasons which included diagnosing impacted teeth or performing other dental examinations. Before conducting this research, we obtained the approval of the ethics committee of the Guilan University of Medical Sciences research foundation (ethics approval number 1390) in Rasht, Iran to ensure our compliance with the recommendations of the declaration of Helsinki and Tokyo for humans including all amendments and revisions.

Digital lateral cephalograms were captured by storage phosphor plate cassettes using a Planmeca Ec Proline machine (Planmeca, Helsinki, Finland). These images were then scanned and digitized using a CR system scanner (Konica Minolta holdings, Inc., Tokyo, Japan). After ensuring the quality of the images and making the desired adjustments to show density and contrast, they were transferred to a PACS system (PACSPLUS, Orange County, CA) as digital imaging and communications in medicine (DICOM) data and then exported to an electronic folder of cephalometric images as jpg.formatted images. Exposure settings were different for various patients. All cephalometric images were prepared by stabilizing the patient's head in a natural position using ear rods.

CBCT images were acquired with a New Tom VG device (QR Srl Company, Verona, Italy) by selecting a 9-inch field of view (FOV) in a head position similar to that in which the patient had been stabilized using cephalometric units but without employing extracranial references (i.e. a ruler and the chain). After first taking the required volumetric images, study images having a 1-mm axial slice thickness were then generated. Lateral 3D images taken in volume model style and in bone model color to show hard and soft tissue aspects were reconstructed using NNT Viewer software, Version 2.21. The Camera Shot tool available in this NNT Viewer software was employed to take a photo from 3D images. These photos were then stored in jpg.format in an electronic 3D image folder.

All digital cephalograms were calibrated in sizes ranging from 160 to 210 mm and had a 290 pixels/inch resolution. These images were then exported to Photoshop software (middle eastern version) for pinpoint detection of normal landmarks (Figure 1). Three fourth-year dental students, who had been trained only in cephalometric analysis in an orthodontic course with the same in-

structor that had more than ten years of teaching experience, were asked to locate 19 normal landmarks. Training in cephalometric analysis had been based on attending lectures and practicing on printed radiographs. The contents of these lectures on cephalometric analysis were based on the demonstration of normal landmarks on skull models and in conventional radiographs. Before detecting specified landmarks, their definitions, as depicted in Table 1, were given to each student observer. Terms are defined by three experienced (10+ years each) orthodontists as co-investigators. For bilateral landmarks, these same observers identified the ones that had more clarity. Then the student observers identified the same normal landmarks on 3D images, including lateral views of 3D-reconstructed hard (Figure 2A) and soft tissue images (Figure 2B) in the same manner as they had done for the previously viewed 2D images.

Figure 1. Pinpoint Detection of Normal Landmarks on Lateral Cephalograms Using Photoshop Software

Afterwards, 2D and 3D images traced by each observer were subsequently transferred to SCANORA software (Sordex, Helsinki, Finland) and the distances of each normal landmark detected by each observer to the anterior and the upper edges were measured by a co-investigator of this

Figure 2. 3D CBCT Images

A

D3

B

D4

A, Lateral view with hard tissue reconstruction; B, Lateral view with soft tissue reconstruction.

study as horizontal (X-) and vertical (Y-) measurements of normal landmarks (Figures 3 and 4A and B).

3.1. Statistical Analysis

Data were entered into SPSS Version 19 software (SPSS, Chicago, IL) and both X- and Y- measurements of each normal landmark as calculated for our 11 subjects in both imaging modalities were compared for our three observers. To determine the best estimate of the true value for each anatomical landmark, we used the average of the three student observers' estimates made of each landmark

Table 1. Definition of Hard and Soft Tissue Landmarks

Landmark	Definition
A-point (A)	Deepest point of the maxillary base between the anterior nasal spine and the alveolar crest
Anterior Nasal Spine (ANS)	Tip of the anterior nasal spine
B-Point (B)	Deepest point in the concavity of the anterior border of the symphysis
Condylion (Con)	The most posterior superior point of the right condyle
Gnathion (Gn)	Midpoint between the most anterior and inferior point on the bony chin
Gonion (Go)	The most convex point where the posterior and inferior curves of the ascending ramus meet each other
Maxillary Incisor Edge (MIE)	Tip of the right maxillary central incisor
Menton (Me)	Most inferior point of the symphysis
Nasion (N)	Most anterior superior point at the intersection of the nasal bone and the nasofrontal suture in the midsagittal plane
Orbitale (Or)	Most inferior point of outer border of the orbital cavity
Pogonion (Pog)	Most anterior point on the midsagittal symphysis
Porion (Po)	Most superior point of the right external auditory canal
Soft Tissue A-Point (A')	Most concave point between the subnasale and the anterior point of upper lip
Soft Tissue B-Point (B')	Most concave point between the lower lip and the soft tissue chin
Soft Tissue Pogonion (Pog')	Most anterior point on the anterior curve of the soft tissue chin
Soft Tissue Nasal Tip (NT)	Most anterior point on the curve of the nose
Subnasale (Sn)	Point where the nose connects to the center of the upper lip
Labrale Inferius (LI)	Most anterior point on the curve of the lower lip
Labrale Superius (LS)	Most anterior point on the curve of the upper lip

as described by Baumrind and Frantz (18) as the gold standard.

To evaluate reliability, we used X- and Y-values, calculated by using the 3D imaging method to allow for reasonable comparison of these distances shown when using the 2D imaging modality. Note Z-values (i.e. depth measurements) were not used to study reliability.

To determine the respective mean errors, we used the average of the absolute value of the difference of our three student observers distance estimation from the best estimation point of each normal landmark location in the X- and Y-directions for both imaging modalities.

Intraclass correlation coefficients (ICCs) were used to determine the agreement levels observed among our student observers. An ICC of less than 85% was considered to be the low level of significant difference. The Bland-Altman test was used to assess the agreement levels between our 2D and 3D methods and to establish the interobserver reliability coefficient (IRC). A P value ≤ 0.05 was considered as statistically significant.

4. Results

In this study, 19 normal anatomical landmarks were evaluated using digital lateral 2D cephalograms and 3D CBCT images of 11 orthodontic patients. Three fourth-year dental students were asked to identify these normal landmarks after calibrating images in both imaging modalities.

Table 2 reveals the best estimation of each anatomical landmark location studied and depicts standard errors made by our observers in each modality when identifying these sites in both X- and Y-directions.

The comparison between mean errors made by our student observers when viewing images in both 2D and 3D imaging modalities is shown in Table 3. According to the Table 3 ANS in the X-direction ($P = 0.001$), N in the Y-direction ($P = 0.014$), Or in the Y-direction ($P < 0.001$) and Pog' in the Y-direction ($P = 0.01$) show statistically significant differences between the two imaging methods. However, in 3D CBCT, the errors or variations of our student observers in the detection of anatomical landmarks were lower than those found in 2D cephalometry. It was the reverse for the detection of Con ($P = 0.033$) and MIE ($P = 0.021$) in the X-direction. A mean error greater than 1mm in the

Figure 4. Measuring Distances of Each Normal Landmark to the Anterior and Upper Borders of the Image in the Lateral Aspect

A, Hard tissue reconstruction; B, Soft tissue reconstruction.

Table 5. Comparison Between Overall Mean Errors Made by Student Observers in Hard and Soft Tissues in Each Imaging Modality^a

Direction	Landmark Status	N	Mean	Standard Deviation	P Value
2D Modality					
X					0.000
	Hard tissue	143	0.9691	1.08877	
	Soft tissue	77	0.3071	0.20465	
Y					0.039
	Hard tissue	143	1.0699	0.97662	
	Soft tissue	77	0.7983	0.81716	
3D Modality					
X					0.031
	Hard tissue	143	1.0233	3.69711	
	Soft tissue	77	0.3469	0.26081	
Y					0.014
	Hard tissue	143	0.9354	1.03248	
	Soft tissue	77	0.6309	0.43509	

^aX, Horizontal direction; Y, Vertical direction; P ≤ 0.05.

Table 6. The Agreement Levels of Student Observers in the Detection of Normal Landmarks When Viewing 2D or 3D Images

Modality	Bias ± SD, mm ^a	Range of bias, mm	95% Limit of Agreement, mm	Interobserver Reliability Coefficient (IRC)
2D	0.8561 ± 0.9419	0 - 7.91	-1.03 - 2.74	1.71
3D	0.7151 ± 0.7959	0 - 4.87	-.88 - 2.31	1.43

^aSD, Standard deviation; Bland-Altman test.

the 2D modality was more difficult than in 3D due to having less soft tissue contrast. The difficulty in correctly detecting the ANS landmark could be due to the superimposition of the shadow of the nasal ala on it. The superimposi-

tion that one side makes on the other side of the face could be the reason for the more difficult detection of Or in 2D modality.

Various studies have revealed that the measurements

on CBCT-generated cephalograms are more accurate than those calculated in conventional cephalograms (22, 23). Kumar et al. (11) has compared conventional cephalograms and CBCT-generated cephalograms on dry skulls and from human samples and have shown that there were no statistically significant differences. In our study, the mean error in the detection of anatomical landmarks in lateral cephalograms was greater than in CBCT. Additional investigations (13, 24) have revealed that the method of imaging is not an important variable in the detection of cephalometric landmarks. However, in this study, our student observers showed greater agreement in the detection of normal landmarks and proved that the imaging modality used, i.e. 3D as compared to 2D is important.

de Oliveira et al. (25) have evaluated the reliability of observers in 3D-landmark identification using CBCT. They showed that 3% of IRCs were < 0.45 . The ICC was reported as > 0.9 for 66% of interobserver assessments. A poor indication of reliability was shown in the Y- and Z-coordinates as indicated by an ICC < 0.45 for two cases (6.66%) in the Y-coordinate and for one case (3.3%) in the Z-coordinate, thereby affecting only three interobserver assessments (3.3%). Two bilateral landmarks, i.e. the right and left ramus in the Y-coordinate and in the right and left Con in the Z-coordinate, showed low ICC scores (25). In our study, no ICC < 0.45 was reported. In only one normal landmark (A in the Y-direction) in 3D and four landmarks in the 2D modality (A and Pog' in the Y-direction as well as ANS and Or in the X-direction), the ICC was reported as < 0.85 . The interobserver ICC in the detection of other normal landmarks was > 0.85 and, thus, considered to be excellent. Overall, only 5% of interobserver assessments in 3D CBCT and 20% of interobserver assessments in using 2D cephalograms were < 0.85 and, therefore, classified as poor.

Perez Couceiro and de Vasconcellos Vilella suggested 3D images are more reliable for the identification of Po, Or, A, B and N landmarks as all of these are difficult to detect in 2D cephalograms. Similarly, the lower mandibular border was identified in 3D modality more easily (26).

In our study ANS, N, Or and Pog' in the Y-direction were detected with less error in 3D than in 2D modality.

Couceiro and Vilella study (26) also assert that the values of the measurements taken from 3D images showed less discrepancy and greater reliability when identifying some cephalometric landmarks. This finding is compatible with Nakajima et al. (27) and our study. Chang et al. (12) have revealed that landmark identification errors on the CBCT-derived cephalograms were greater for N, Or, and ANS and less for Pog, Gn, Me, and basion landmarks. In our study, landmark identification errors in digital lateral cephalograms were also greater for ANS, N, Or and Pog'

than those made on 3D CBCT images.

In our study, mean errors in the detection of normal landmarks located on lateral sides were more frequently made in identifying midsagittal landmarks in both modalities. This finding is compatible with Kumar et al. (13) and Gribel et al. (23) Greater lateral landmark identification errors e.g Or could be related those of a physical character because many observers had experienced difficulty in detecting landmarks on blurred images of superimposed bilateral structures (16). Ludlow et al. (28) have reported that the reliability of 3D landmark identification on CBCT volumetric images was more precise for bilateral landmarks such as Go and Or as compared with conventional 2D cephalograms.

Overall, our mean student observer errors in locating of soft tissue landmarks were less frequently made in 3D than in 2D modality. Even the agreement of these observers in locating soft tissue landmarks was greater than detecting hard tissue ones. This is related to the character of soft tissue landmarks located in the midsagittal plane that show less superimposition and have proper contrast resolution.

The teaching program of our orthodontics course on the topic of lateral cephalogram tracing was based on having students identify cephalometric landmarks on radiographs after they had imagined those same points on the skull while attending lectures that had been accompanied by PowerPoint slide presentations. Then the students had to find and trace the landmarks on the printed radiographs themselves and review them with their professors or they were asked to detect new landmarks using an interactive model. This method of teaching seems to be effective in enhancing the ability of dental students to locate anatomical landmarks on CBCT without their having to undergo special training.

5.1. Conclusion

Mean observer errors in detecting anatomical landmarks in 2D lateral cephalograms were greater than in 3D CBCT modality, but they were not statistically significant. In both methods, our student observers in the detection of the midsagittal plane and soft tissue landmarks also showed greater agreement. Therefore, the training of 2D cephalometric analysis based on 3D imagination for dental students could be helpful in 3D CBCT analysis.

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Table 2. The Best Estimation of and Standard Errors Made in Identifying Each Landmark Location When Using 2D and 3D Imaging Modalities^a

Directions of Modality	Estimate	Standard Error	95% Confidence Interval	
			Lower Boundary	Upper Boundary
Landmark A				
2D				
X	40.96	1.66	37.13	44.79
Y	127.45	2.52	121.63	133.26
3D				
X	58.07	4.57	47.54	68.6
Y	124.93	3.26	117.42	132.45
Landmark ANS				
2D				
X	37.37	1.84	33.11	41.62
Y	119.18	1.6	115.48	122.87
3D				
X	54.92	5.92	41.26	68.58
Y	114.69	2.71	108.44	120.94
Landmark B				
2D				
X	49.87	2.34	44.47	55.27
Y	168.01	3.12	160.83	175.2
3D				
X	70.69	5.12	58.88	82.51
Y	188.31	4.4	178.17	198.46
Landmark Con				
2D				
X	134.74	2.16	129.76	139.71
Y	95.53	3.44	87.59	103.46
3D				
X	218.54	6.83	202.78	234.29
Y	70.86	8.34	51.63	90.08
Landmark Gn				
2D				
X	51.93	2.29	46.66	57.2
Y	190.9	1.73	186.92	194.89
3D				
X	73.99	5.12	62.18	85.81
Y	224.15	4.39	214.03	234.26
Landmark Go				
2D				
X	129.02	2.72	122.74	135.29
Y	154.35	2.44	148.73	159.98
3D				
X	206.72	5.84	193.24	220.19
Y	161.86	4.49	151.5	172.22
Landmark MIE				
2D				
X	38.6	2.67	32.44	44.76
Y	151.71	2.83	145.19	158.24
3D				
X	53.76	4.15	44.19	63.33
Y	164.36	2.84	157.81	170.92
Landmark Me				
2D				
X	59.02	2.48	53.3	64.74

Y	192.14	1.51	188.66	195.62
3D				
X	83.4	4.57	72.87	93.94
Y	226.56	4.71	215.69	237.43
Landmark N				
2D				
X	42.32	2.15	37.36	47.28
Y	58.6	3.09	51.47	65.73
3D				
X	56.29	9.1	35.31	77.28
Y	82.13	12.72	52.79	111.46
Landmark Or				
2D				
X	61.72	1.8	57.56	65.88
Y	91.69	2.92	84.95	98.43
3D				
X	86.39	5.33	74.11	98.67
Y	60.2	4.4	50.05	70.35
Landmark Pog				
2D				
X	61.22	2.14	56.28	66.17
Y	173.28	10.45	149.18	197.39
3D				
X	70.08	4.57	59.54	80.62
Y	214.65	5.04	203.03	226.26
Landmark Po				
2D				
X	148.49	1.83	144.28	152.71
Y	91.35	2.96	84.53	98.16
3D				
X	228.61	6.43	213.78	243.44
Y	86.46	13.42	55.52	117.4
Landmark A'				
2D				
X	25.42	1.55	21.84	29
Y	131.92	2.82	125.42	138.42
3D				
X	33.33	5.61	20.39	46.27
Y	137.67	2.53	131.83	143.5
Landmark B'				
2D				
X	37.22	2.37	31.76	42.68
Y	168.92	2.06	164.16	173.68
3D				
X	52.92	2.21	47.82	58.02
Y	189.58	2.67	183.42	195.73
Landmark Pog'				
2D				
X	33.78	2.81	27.3	40.27
Y	183.07	2.07	178.3	187.84
3D				
X	50.75	5.45	38.17	63.32
Y	205.89	2.43	200.3	211.49
Landmark NT				
2D				
X	7.13	1.16	4.47	9.8
Y	110.47	2.73	104.17	116.77

3D				
X	13.09	2.85	6.53	19.65
Y	150.13	16.8	111.38	188.88
Landmark Sn				
2D				
X	23.52	1.1	20.99	26.06
Y	124.51	3.45	116.55	132.48
3D				
X	29.63	5.74	16.4	42.86
Y	125.13	2.81	118.66	131.61
Landmark LI				
2D				
X	27.69	1.94	23.22	32.16
Y	161.63	2.91	154.92	168.33
3D				
X	39.38	5.61	26.45	52.31
Y	179.56	2.77	173.16	185.95
Landmark I5				
2D				
X	22.22	1.54	18.66	25.78
Y	138.9	3.12	131.7	146.1
3D				
X	29.72	4.9	18.42	41.01
Y	147.27	2.12	142.38	152.16

^aX, Horizontal direction; Y, Vertical direction.

Table 3. A Comparison Between Mean Errors Made by Our Three Student Observers in the Detection of Landmarks Observed in 2D and 3D Images (Number = 11) For Each Direction^a

Directions of Modality	Mean Error	Standard Deviation	P Value
Landmark A			
X			
2D	0.6869	0.83364	0.293
3D	0.404	0.24299	
Y			
2D	1.6525	1.70148	0.476
3D	2.1818	1.71408	
Landmark ANS			
X			
2D	2.8566	2.05686	0.001
3D	0.3091	0.1941	
Y			
2D	0.8081	0.54896	0.021
3D	0.3576	0.22867	
Landmark B			
X			
2D	0.3939	0.39228	0.55
3D	0.4909	0.35576	
Y			
2D	1.4343	1.14177	0.979
3D	1.4465	1.0403	
Landmark Con			
X			
2D	1.6	0.63191	0.033
3D	2.2808	0.75531	
Y			
2D	1.5434	1.11126	0.798
3D	1.6424	0.61169	
Landmark Gn			
X			
2D	0.6889	0.41276	0.268
3D	0.9737	0.71993	
Y			
2D	0.7354	0.27079	0.502
3D	0.8505	0.4891	
Landmark Go			
X			
2D	1.0727	0.52504	0.139
3D	0.7111	0.574	
Y			
2D	0.8404	0.52265	0.42
3D	1.0303	0.55948	
Landmark MIE			
X			
2D	0.1879	0.12186	0.021
3D	0.3838	0.22816	
Y			
2D	0.3434	0.1628	0.051
3D	0.202	0.15602	
Landmark Me			
X			
2D	1.2101	0.75806	0.46

3D	1.5253	1.1611	
Y			
2D	0.4909	0.39006	0.496
3D	0.3919	0.2693	
Landmark N			
X			
2D	0.2747	0.15048	0.341
3D	0.2182	0.12001	
Y			
2D	0.897	0.76544	0.014
3D	0.2667	0.10135	
Landmark Or			
X			
2D	2.1818	0.98049	0.553
3D	4.5697	13.0777	
Y			
2D	0.9939	0.41265	0
3D	0.3172	0.17187	
Landmark Pog			
X			
2D	0.3818	0.66643	0.739
3D	0.4687	0.53384	
Y			
2D	1.7232	0.96396	0.364
3D	2.1758	1.29613	
Landmark Po			
X			
2D	0.7879	0.3259	0.416
3D	0.6444	0.47057	
Y			
2D	1.9535	1.36512	0.106
3D	1.0465	1.13779	
Landmark A'			
X			
2D	0.3172	0.14643	0.614
3D	0.3475	0.13044	
Y			
2D	1.2222	1.04596	0.506
3D	0.9636	0.7148	
X			
2D	0.2889	0.16895	0.212
3D	0.198	0.16192	
Y			
2D	0.3414	0.20662	0.592
3D	0.3859	0.17449	
Landmark Pog'			
X			
2D	0.2182	0.16594	0.303
3D	0.3091	0.2321	
Y			
2D	1.8303	1.1249	0.01
3D	0.7616	0.53869	
Landmark NT			
X			
2D	0.2	0.13481	0.897
3D	0.1919	0.15373	
Y			

2D	0.7919	0.77059	0.303
3D	0.5313	0.27207	
Landmark Sn			
X			
2D	0.4	0.24845	0.265
3D	0.5535	0.36804	
Y			
2D	0.4646	0.1892	0.107
3D	0.6303	0.26523	
Landmark LI			
X			
2D	0.3939	0.29882	0.19
3D	0.5616	0.28058	
Y			
2D	0.3939	0.18542	0.057
3D	0.6182	0.31737	
Landmark LS			
X			
2D	0.3313	0.17707	0.377
3D	0.2667	0.15776	
Y			
2D	0.5434	0.19022	0.885
3D	0.5253	0.36342	

^a X, Horizontal direction; Y, Vertical direction; $P \leq 0.05$.

Table 4. Interobserver Reliability Intraclass Correlation Coefficients in the Detection of Anatomical Landmarks When Using 2D and 3D Imaging Methods^a

Modalities of Direction	ICC	95% Confidence Interval		P Value
		Lower Boundary	Upper Boundary	
Landmark A				
2D				
X	0.956	0.878	0.987	0.009
Y	0.897	0.714	0.97	0.227
3D				
X	0.999	0.996	1	0
Y	0.921	0.781	0.977	0.106
Landmark ANS				
2D				
X	0.752	0.312	0.927	0.792
Y	0.988	0.967	0.997	0
3D				
X	0.999	0.998	1	0
Y	0.996	0.989	0.999	0
Landmark B				
2D				
X	0.991	0.975	0.997	0
Y	0.951	0.865	0.986	0.015
3D				
X	0.998	0.995	0.999	0
Y	0.984	0.957	0.995	0
Landmark Con				
2D				
X	0.976	0.934	0.993	0
Y	0.962	0.894	0.989	0.004
3D				
X	0.996	0.989	0.999	0
Y	0.999	0.996	1	0
Landmark Gn				
2D				
X	0.988	0.966	0.996	0
Y	0.99	0.972	0.997	0
3D				
X	0.994	0.984	0.998	0
Y	0.995	0.987	0.999	0
Landmark Go				
2D				
X	0.977	0.935	0.993	0
Y	0.985	0.957	0.995	0
3D				
X	0.998	0.994	0.999	0
Y	0.995	0.985	0.998	0
Landmark MIE				
2D				
X	0.999	0.997	1	0
Y	0.998	0.994	0.999	0
3D				
X	0.999	0.998	1	0
Y	0.999	0.998	1	0
Landmark Me				
2D				
X	0.946	0.849	0.984	0.025

Y	0.989	0.969	0.997	0
3D				
X	0.983	0.952	0.995	0
Y	0.998	0.996	1	0
Landmark N				
2D				
X	0.996	0.989	0.999	0
Y	0.973	0.925	0.992	0.001
3D				
X	1	1	1	0
Y	1	1	1	0
Landmark Or				
2D				
X	0.914	0.761	0.975	0.14
Y	0.99	0.971	0.997	0
3D				
X	0.994	0.983	0.998	0
Y	0.999	0.997	1	0
Landmark Pog				
2D				
X	1	0.999	1	0
Y	0.999	0.996	1	0
3D				
X	0.998	0.994	0.999	0
Y	0.979	0.943	0.994	0
Landmark Po				
2D				
X	0.969	0.915	0.991	0.001
Y	0.959	0.887	0.988	0.006
3D				
X	0.997	0.993	0.999	0
Y	0.999	0.997	1	0
Landmark A'				
2D				
X	0.991	0.974	0.997	0
Y	0.974	0.927	0.992	0
3D				
X	0.999	0.998	1	0
Y	0.974	0.929	0.993	0
Landmark B'				
2D				
X	0.997	0.992	0.999	0
Y	0.995	0.985	0.998	0
3D				
X	1	0.999	1	0
Y	0.996	0.988	0.999	0
Landmark Pog'				
2D				
X	0.998	0.996	1	0
Y	0.86	0.613	0.959	0.424
3D				
X	0.999	0.998	1	0
Y	0.97	0.918	0.991	0.001
Landmark NT				
2D				
X	0.995	0.985	0.998	0
Y	0.98	0.945	0.994	0

3D				
X	0.999	0.997	1	0
Y	1	0.999	1	0
Landmark Sn				
2D				
X	0.987	0.963	0.996	0
Y	0.996	0.99	0.999	0
3D				
X	0.998	0.993	0.999	0
Y	0.989	0.97	0.997	0
Landmark LI				
2D				
X	0.992	0.979	0.998	0
Y	0.996	0.988	0.999	0
3D				
X	0.998	0.994	0.999	0
Y	0.995	0.986	0.999	0
Landmark I5				
2D				
X	0.996	0.988	0.999	0
Y	0.998	0.993	0.999	0
3D				
X	1	0.999	1	0
Y	0.983	0.954	0.995	0

^aICC, Intraclass Correlation Coefficient; X, Horizontal direction; Y, Vertical direction; $P \leq 0.05$.