Reliability of Cone Beam CT for Morphometry of Nasolabial Soft Tissue in Patients with Skeletal Class III Malocclusion: A Qualitative and Quantitative Analysis

Wenjie Xu

Stomatological Hospital of Chongqing Medical University

Rui Lu

Stomatological Hospital of Chongqing Medical University

Yun Hu

Stomatological Hospital of Chongqing Medical University

Li Cao

Stomatological Hospital of Chongqing Medical University

Tao Wang

Stomatological Hospital of Chongqing Medical University

Hao Tan

Stomatological Hospital of Chongqing Medical University

Xuehuan Meng

Stomatological Hospital of Chongqing Medical University

Ye Ming

Stomatological Hospital of Chongqing Medical University

Leilei Zheng (✉ zhengleileicqmu@hospital.cqmu.edu.cn)

Stomatological Hospital of Chongqing Medical University

Research Article

Keywords: cone-beam computed tomography, facial scanner, three-dimensional cephalometry

Posted Date: August 11th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-757829/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at Journal of X-Ray Science and Technology on October 29th, 2021. See the published version at <https://doi.org/10.3233/XST-211018>.

Abstract

Background Precise measurement of the morphological structure of soft and hard tissues is fundamental to the treatment of malocclusion, but the ability of cone beam CT (CBCT) for soft tissue measurements involves few studies to date. The purpose of this study was to assess the reliability of CBCT for nasolabial soft tissue measurements in patients with skeletal class III malocclusion based on 3-dimensional (3D) facial scanner results.

Methods CBCT and 3D facial scan images of 20 orthognathic patients were used in this study. 11 soft tissue landmarks and 15 linear and angular measurements were identified and performed. For qualitative evaluation, Shapiro-Wilk Test and Bland-Altman plots were applied to analyze the equivalence of the measurements derived from these two kinds of data. To quantify specific deviation of CBCT measurements from facial scanner, the latter were set as a benchmark, and mean absolute difference (MAD) and relative error magnitude (REM) for each variable were calculated.

Results Statistically significant differences were observed on length measurements of bilateral philtrum crests, width of mouth and angular measurements of the protrusion angle of lower lip, left angle of upper mouth and nasolabial angle between the two methods. The MAD value for all length measurements were less than 2 mm and for angular variables $<8^\circ$. The average MAD and REM for length measurements was 0.94mm and 5.64% respectively, and 2.27° , 3.78% for angular measurements.

Conclusions Certain inconformity exists in regions of nasal base and lower lip vermilion between CBCT and facial scanner when measuring nasolabial surfaces, but most of them are clinically acceptable. The soft tissue results measured by CBCT showed relatively good reliability and can be used for 3D measurement of soft tissue in the nasolabial region clinically.

Background:

Cephalometric measurement and analysis serve as an indispensable part in clinical diagnosis and treatment of dento-maxillofacial deformities for orthodontics as well as orthognathic surgeons. Traditional 2-dimensional (2D) radiological imaging such as lateral and posteroanterior radiography have been widely used in the clinic. As imaging techniques and associated tools continue to mature, the application of 3D images in cephalometry has been put on the agenda [1-5].

Cone-beam computed tomography (CBCT) is developed specially for the treatment of oral and maxillofacial diseases, whose wide application is attributed to the advantages such as low radiation dose, low cost and strong interactivity [6-8]. But its use in cephalometry for the treatment of dento-maxillofacial deformities is still in infancy [9]. Digital-assisted orthognathic surgery using CBCT is a relatively mature technique recently, but the simulation is limited to the postoperative morphology of bony tissue, and soft tissue simulation remains far out of reach [10-12]. The postoperative prediction of soft tissue changes, therefore, is regarded as one of the current difficulties by scholars, but is also of utmost concern to patients [13-15].

The prediction of soft tissue changes is dependently based on the precise measurement of their morphological characteristics, which has been made possible by the development of 3D imaging techniques. Facial scanner is a well-established device currently used in the clinic, which can record the texture and characteristics of facial skin three-dimensionally, leading clinicians to be increasingly accurate in studying changes in facial soft tissue before and after treatment. Commonly used are 3DMD, Morpheus 3D, etc., and their precision and accuracy have been verified by previous studies [16-19]. Nevertheless, facial scanner can only record the morphology of soft tissues, which needs to be fused with CBCT when to explore the relationships and ratios of soft and hard tissues [20,21], thus possibly bringing the technical error when the two data fuse, which in turn affects the measurement results, and soft tissues imaged by CBCT avoid this problem [22].

Three-dimensional cephalometric technique based on CBCT is one of the hot topics in orthodontic and orthognathic clinical research in recent years [23-25]. Traditionally, cephalometric measurements involve both soft and hard tissues. There is no doubt about the ability of CBCT for hard tissue measurements, whereas its ability to measure soft tissue morphology involves fewer studies to date. Precise measurement of the morphological structure of soft and hard tissues is fundamental to the development of 3D cephalometric techniques, and thus deserve intensive study.

The purpose of this study, therefore, was to qualitatively analyze whether CBCT reconstructed facial soft tissue models show statistically significant differences compared with 3D facial scanner when used for soft tissue morphometry. Meanwhile, using 3D facial scanner measurements as a benchmark, to quantitatively analyze the degree of specific deviation of the CBCT measurement variables, so as to provide reference and guidance for the clinical application of CBCT in soft tissue measurement and 3D cephalometric analysis, and finally promote the clinical use of CBCT.

Methods:

Samples selection

This study was carried out at the Department of Stomatological Hospital of Chongqing Medical University, China after the ethical approval and study protocol was approved (CQHS-REC-2021001). Written informed consent for the participation in the study and the publication of their identifying images in an online open-access publication platform has been obtained from all subjects. We confirm that all methods were performed in accordance with the relevant guidelines and regulations.

The CBCT and 3D facial scan images of 20 orthognathic patients (ten women) were used. Two types of image were taken at the same time for diagnostic purposes. All patients underwent the same surgery procedure-maxillary Le Fort I osteotomy and mandibular bilateral sagittal splint ramus osteotomy to treat skeletal class III malocclusion, which were performed by a same surgeon from the above hospital. Patients with congenital syndromes, systematic diseases, cleft lip /palate, temporomandibular joint disorder or facial trauma were excluded.

Data acquisition

CBCT (KaVo Dental Gmb H, USA; 80 mA, 8.9-second scan time) scans were acquired at a 0.4 mm* 0.4 mm* 0.4 mm voxel size level and set at a matrix of 400 × 400 pixels in each CT slice and a 0.25 mm slice thickness. The CBCT data were then stored into a specialized computer in Digital Imaging and Communications in Medicine (DICOM) format, and were converted in to 3D models for measurement with a 3D reconstruction software, Mimics 19.0, (Materialise, Leuven, Belgium). To obtain the optimal facial soft tissue models, the threshold values for Hounsfield units(HU)were set as -718 to -177 HU and smooth procedure was performed. After these processes, the 3D facial soft tissue images reconstructed by CBCT were obtained.

The facial scanner Morpheus 3D (Morpheus, Gyoung-gi, Korea) was used for 3D facial surface scan, which emitted white structured light to the patient and fine texture of facial skin can be obtained. Other parameters of this device included a scan time of 0.8 seconds, a scan accuracy of 0.1mm and an image resolution of 1024x768 ppi. After scanning process, the images were then auto-synthesized by the MDS software of the device (Morpheus, Gyoung-gi, Korea), and the 3D facial scan models were obtained.

Variables measurement

11 soft tissue landmarks and 15 linear and angular measurement variables were used in this study (Figure 1, Figure 2 and Table 1). Landmarks location and variables measurement were performed in CBCT model and 3D facial scan models respectively using a mouse-driven graphics cursor in 3D view. To assess the intra-observer reproducibility, the first author located the landmarks twice at an interval of 2 weeks, and the intra-class correlation (ICC) analysis was performed at 95% confidence intervals. All variables were measured twice in two-week interval by the same operator, and the mean of the two measured values was used for final statistical analysis.

Table 1

Definition of landmarks and measurements in this study

Item	Definition
Cm	The uppermost point of the nasal columella
Sn	The midpoint of the turning between the skin of the upper lip and the root of the nasal columella
Sbal (L/R)	The turning point of philtrum crest and nasal columella (Left side/Right side)
Cph (L/R)	The highest point of the arch of the upper lip (Left side/Right side)
Ch (L/R)	The outermost point of the oral cleft junction (Left side/Right side)
Ls	Midpoint of the vermilion border of the upper lip
Li	Midpoint of the vermilion border of the lower lip
Length of PC(L/R)	Distance from Sbal to Cph (Left side/Right side)
Width of the mouth	Distance from ChL to ChR
Vermilion thickness of UL	Distance from Ls to Stmo
Vermilion thickness of LL	Distance from Li to Stmo
Protrusion angle of UL	$\angle \text{ChL-Ls-ChR}$
Protrusion angle of LL	$\angle \text{ChL-Li-ChR}$
Angle of UM (L/R)	$\angle \text{Cph-Ch-Stmo}$ (Left side/Right side)
Angle of LM (L/R)	$\angle \text{Cph-Ch-Stmo}$ (Left side/Right side)
Angle of CB (L/R)	$\angle \text{Ch-Cph-Ls}$ (Left side/Right side)
Central angle of CB	$\angle \text{CphL-Ls-CphR}$
Nasolabial angle	$\angle \text{Cm-Sn-Ls}$
PC, the philtrum crest; UL, the upper lip; LL, the lower lip; UM, the upper mouth; LM, the lower mouth; CB, the Cupid's bow.	

Statistical analysis

The data of this study were analyzed using SPSS 26.0 software (IBM Co., Armonk, NY, USA) and MedCalc Software (version 20.009, Ostend, Belgium) For qualitative evaluation, the Shapiro-Wilk Test was applied to analyze the distribution characteristics of the data and the Bland-Altman plots was used to analyze the equivalence between measurements derived from these two kinds of model. To determine the equivalence of the 2 methods, the line of equality (difference=0) must contain entirely within the 95%

confidence interval of their mean difference. To quantify specific deviation of CBCT measurements from facial scanner, the results of the latter were set as a benchmark, and mean absolute difference(MAD) and relative error magnitude(REM) for each variable were calculated. The calculation was performed as follows:

$$MAD = \frac{1}{20} \sum_i^{20} |CBCT_i - 3Dfacialscan_i|$$

$$REM = \frac{1}{20} \sum_i^{20} \frac{|CBCT_i - 3Dfacialscan_i|}{3Dfacialscan_i}$$

Results:

The high ICC value (ranging from 0.894 to 0.913) indicated good intra-observer reliability in this study, and the Shapiro-Wilk Test results showed that the data fit a normal distribution. **Table 2** shows linear and angular measurement results of the facial scanner and CBCT respectively.

Table 2

Measurement results of CBCT and facial scanner

Measurement Variables	CBCT	FS
length of pc(L,mm)	12.95±2.18	14.49±2.29
length of pc(R,mm)	12.68±2.15	14.92±2.27
width of mouth(mm)	48.71±4.50	46.62±4.06
Vermilion thickness of UL(mm)	7.73±2.29	8.13±2.01
Vermilion thickness of LL(mm)	10.11±1.80	10.35±1.87
Protrusion angle of UL(°)	114.33±10.24	110.34±7.77
Protrusion angle of LL(°)	118.33±7.52	111.88±5.08
Angle of UM (L°)	23.85±5.66	25.90±5.77
Angle of UM (R°)	24.95±5.16	26.52±4.20
Angle of LM (L°)	20.70±4.19	21.59±5.64
Angle of LM (R°)	21.32±3.86	22.67±6.13
Angle of CB (L°)	131.94±9.70	130.09±8.46
Angle of CB (R°)	127.34±9.84	129.11±8.66
Central angle of CB(°)	131.82±12.18	135.34±9.49
Nasolabial angle(°)	84.84±15.34	98.06±10.36

L, the left side; R, the right side; PC, the philtrum crest; UL, the upper lip; LL, the lower lip; UM, the upper mouth; LM, the lower mouth; CB, the Cupid's bow; FS, facial scanner. L, the left side; R, the right side; PC, the philtrum crest; UL, the upper lip; LL, the lower lip; UM, the upper mouth; LM, the lower mouth; CB, the Cupid's bow; FS, facial scanner.

In **Table 3** and **Figure 3-5**, Bland-Altman plots show the difference between the mean of linear and angular measurements of CBCT and facial scanner in each variable. According to the results, there are statistical differences between facial scanner and CBCT in the variables of the length of philtrum crest on both sides, width of mouth, the protrusion angle of the lower lip, angle of upper mouth on the left side and the nasolabial angle.

Table 3

Equivalence analysis of measurements between CBCT and FS

Measurement Variables	Mean(95%CI)	Equivalence
length of pc(L,mm)	-1.54(-2.15,-0.94)	N
length of pc(R,mm)	-2.24(-2.73,-1.75)	N
width of mouth(mm)	2.09(0.52,3.67)	N
Vermilion thickness of UL(mm)	-0.40(-0.95,0.15)	Y
Vermilion thickness of LL(mm)	-0.24(-1.12,0.64)	Y
Protrusion angle of UL(°)	3.99(-0.27,7.71)	Y
Protrusion angle of LL(°)	6.45(4.17,8.73)	N
Angle of UM (L°)	-2.04(-3.57,-0.51)	N
Angle of UM (R°)	-1.57(-2.99,0.14)	Y
Angle of LM (L°)	-0.89(-2.77,0.99)	Y
Angle of LM (R°)	-1.35(-3.33,0.62)	Y
Angle of CB (L°)	1.86(-0.86,4.57)	Y
Angle of CB (R°)	-1.76(-4.37,0.86)	Y
Central angle of CB(°)	-3.51(-7.59,0.56)	Y
Nasolabial angle(°)	-13.21(-19.23,-7.20)	N

L, the left side; R, the right side; PC, the philtrum crest; UL, the upper lip; LL, the lower lip; UM, the upper mouth; LM, the lower mouth; CB, the Cupid's bow; FS, facial scanner; N, NO; Y, YES.

The quantitative analysis results of linear and angular measurement differences between facial scanner and CBCT are shown in **Table 4** and **Table 5**. For linear measurements, the average MAD was 0.94mm and the average REM was 5.64%, and the larger differences manifested in the length of bilateral philtrum crests and the width of the mouth (MAD>1mm). For angular measurements, the average MAD was 2.27° and the average REM was 3.78% and the larger differences exhibited in the protrusion angle of the lower lip and the nasolabial angle(MAD>7°).

Table 4

Linear measurement deviation of CBCT from facial scanner

Measurement	MAD(mm)		REM(%)	
Variables(mm)	Mean	SD	Mean	SD
length of pc(L)	1.45	1.12	9.93	1.12
length of pc(R)	1.52	0.98	9.88	0.98
width of mouth	1.21	3.45	2.63	3.45
Vermilion thickness of UL	0.33	1.03	3.80	1.03
Vermilion thickness of LL	0.20	1.79	1.98	1.79
Average	0.94	0.63	5.64	3.94

L, the left side; R, the right side; PC, the philtrum crest; UL, the upper lip; LL, the lower lip; MAD, mean absolute difference; REM, relative error magnitude; SD, standard deviation.

Table 5
Angular measurement deviation of CBCT from facial scanner

Measurement	MAD(°)		REM(%)	
Variables(°)	Mean	SD	Mean	SD
Protrusion angle of UL	3.02	7.56	2.84	7.56
Protrusion angle of LL	7.17	4.48	6.20	4.48
Angle of UM (L)	1.72	3.30	6.37	3.30
Angle of UM (R)	1.50	3.23	5.47	3.23
Angle of LM (L)	0.44	3.09	1.97	3.09
Angle of LM (R)	0.73	3.72	3.13	3.72
Angle of CB (L)	1.81	6.17	1.42	6.17
Angle of CB (R)	1.18	6.16	0.92	6.16
Central angle of CB	2.54	8.78	1.90	8.78
Nasolabial angle	7.55	6.39	7.54	6.39
Average	2.27	2.54	3.78	2.39

L, the left side; R, the right side; UL, the upper lip; LL, the lower lip; UM, the upper mouth; LM, the lower mouth; CB, the Cupid's bow; MAD, mean absolute difference; REM, relative error magnitude; SD, standard deviation.

Discussion:

In this study, 20 CBCT and 3D facial scan data of skeletal class III patients were combined to explore the reliability of CBCT for soft tissue measurements, and the nasolabial region was selected as the research structure. One consideration was based on the special structure of this region- vermilion mucosa and the skin [26]. Since the two structure cannot be distinguished on CBCT images, we sought to explore how accurate the measurements of CBCT are for that, and whether it has an impact on clinical use. The second was its diverse morphological measurements, including the length, angle and symmetry in 3D space, which can cover feature measurements of many areas of the face [27,28].

The results of qualitative evaluation showed that the difference between CBCT and facial scanner in measuring nasolabial structures mainly manifested in the length of philtrum crest on both sides, width of mouth, the protrusion angle of the lower lip, angle of upper mouth on the left side and the nasolabial angle. Maal et al [29] reported that 90% of soft tissues reconstructed by CBCT showed no difference when matched with 3D facial photographs, and the remaining 10% were affected by head position and facial

expression at the process of image acquisition. In the present study, statistically significant differences were mainly centered on structures located at the nasal base and lower lip, involving bilateral philtrum length and nasolabial angle in the upper lip and the protrusion angle of lower lip. Due to the complex concave characteristics of the nasal base, the accuracy of the landmarks located in this region is compromised [17]. In contrast, landmarks at the junction of the vermilion and skin of the upper lip are easier to identify because of their well-defined characteristic structures like the Cupid's bow. The accuracy of measurements of the lower lip is mainly affected by the Li-point, which was defined as the midpoint of the vermilion border of the lower lip by wong et al [30]. Given the reality that the boundary between the vermilion and the skin is not clear on CBCT and the absence of explicit contour structure like the upper lip, thus making its positioning with suboptimal accuracy.

On quantitative analysis, the mean absolute difference in length measurements of CBCT for all variables were less than 2 mm. In the literature, scholars [31,32] reported that clinically acceptable deviations of soft tissue measurements were ranging from 1-3 mm according to the number of landmarks utilized. In this experiment, variables with relatively obvious deviation were the length of bilateral philtrum crests and the oral width, but none of them exceeded 2 mm, thus can be considered as no impact on clinical use. For angular measurements, the deviation of protrusion angle of lower lip and nasolabial angle were both $> 7^\circ$, but were still classified as good measurements [33,34]. For one thing, the angle measurements involve more landmarks, so the corresponding error becomes larger inevitably. For another, according to findings by Andrade et al [32], the deviation of 3D tools in measuring concave surface structure is relatively large, such as nasolabial angle and mentolabial angle. Patients with skeletal Class III have a smaller nasolabial angle due to insufficient maxillary development, which makes the measurement of this area more difficult. Therefore, in clinical use, one should pay much attention to control the technical error of this region, such as locating the landmarks with a multidimensional view and taking the mean value of multiple measurements.

Conclusion:

L, the left side; R, the right side; PC, the philtrum crest; UL, the upper lip; LL, the lower lip; UM, the upper mouth; LM, the lower mouth; CB, the Cupid's bow; CBCT, cone-beam computed tomography; FS, facial scanner; N, NO; Y, YES; MAD, mean absolute difference; REM, relative error magnitude; SD, standard deviation; ICC, intra-class correlation; 2D, 2-dimensional; 3D, 3-dimensional.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Ethics Committee of Stomatological Hospital of Chongqing Medical University. Written informed consent has been obtained from the participants prior to data collection process.

We confirm that all methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Written informed consent for the publication of their identifying images in an online open-access publication platform has been obtained from all subjects.

Availability of data and materials

The datasets used in the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by Medical Research Key Project of Chongqing Science and Technology Commission and Health and Family Planning Commission Joint (Grant number 2018ZDXM020).

Authors' contributions

WX: acquisition and measurement of the study data; drafting the manuscript.

RL: acquisition of the study data; analysis of the study data.

YH: design of the work.

LC: statistics of the study data.

TW: analysis of the study data.

HT, XM and YM: acquisition of the study data.

LZ: design of the work and revise the manuscript.

Acknowledgements

Not applicable.

Authors' information

1. Department of Stomatological Hospital of Chongqing Medical University, Chongqing, China.
2. Chongqing Key Laboratory of Oral Diseases and Biomedical Sciences, Chongqing, China.
3. Chongqing Municipal Key Laboratory of Oral Biomedical Engineering of Higher Education, Chongqing, China.

References

1. Dot G, Rafflenbeul F, Arbotta M, Gajny L, Rouch P, Schouman T. Accuracy and reliability of automatic three-dimensional cephalometric landmarking. *Int J Oral Maxillofac Surg* 2020;49:1367–78.
2. Zhang D, Wang S, Li J, Zhou Y. Novel method of constructing a stable reference frame for 3-dimensional cephalometric analysis. *Am J Orthod Dentofacial Orthop* 2018;154:397–404.
3. Naji P, Alsufyani NA, Lagraverre MO. Reliability of anatomic structures as landmarks in three-dimensional cephalometric analysis using CBCT. *Angle Orthod* 2014;84:762–72.
4. Han MD, Momin MR, Munaretto AM, Hao S. Three-dimensional cephalometric analysis of the maxilla: Analysis of new landmarks. *Am J Orthod Dentofacial Orthop* 2019;156:337–44.
5. Leung MY, Leung YY. Three-dimensional evaluation of mandibular asymmetry: a new classification and three-dimensional cephalometric analysis. *Int J Oral Maxillofac Surg* 2018;47:1043–51.
6. Kamburoglu K. Use of dentomaxillofacial cone beam computed tomography in dentistry. *World J Radiol* 2015;7:128–30.
7. Gaeta-Araujo H, Alzoubi T, Vasconcelos KF, Orhan K, Pauwels R, Casselman JW, et al. Cone beam computed tomography in dentomaxillofacial radiology: a two-decade overview. *Dentomaxillofac Radiol* 2020;49:20200145.
8. Suomalainen A, Pakbaznejad Esmaeili E, Robinson S. Dentomaxillofacial imaging with panoramic views and cone beam CT. *Insights Imaging* 2015;6:1–16.
9. Pittayapat P, Limchaichana-Bolstad N, Willems G, Jacobs R. Three-dimensional cephalometric analysis in orthodontics: a systematic review. *Orthod Craniofac Res* 2014;17:69–91.
10. Kwon TG, Miloro M, Han MD. How Accurate Is 3-Dimensional Computer-Assisted Planning for Segmental Maxillary Surgery? *J Oral Maxillofac Surg* 2020;78:1597–608.
11. Liao YF, Chen YA, Chen YC, Chen YR. Outcomes of conventional versus virtual surgical planning of orthognathic surgery using surgery-first approach for class III asymmetry. *Clin Oral Investig* 2020;24:1509–16.
12. Kim JW, Kim JC, Jeong CG, Cheon KJ, Cho SW, Park IY, et al. The accuracy and stability of the maxillary position after orthognathic surgery using a novel computer-aided surgical simulation system. *BMC Oral Health* 2019;19:18.
13. Kaipatur NR, Flores-Mir C. Accuracy of computer programs in predicting orthognathic surgery soft tissue response. *J Oral Maxillofac Surg* 2009;67:751–9.

14. Lu CH, Ko EW, Huang CS. The accuracy of video imaging prediction in soft tissue outcome after bimaxillary orthognathic surgery. *J Oral Maxillofac Surg* 2003;61:333–42.
15. Suh HY, Lee HJ, Lee YS, Eo SH, Donatelli RE, Lee SJ. Predicting soft tissue changes after orthognathic surgery: The sparse partial least squares method. *Angle Orthod* 2019;89:910–6.
16. Buyukcavus MH, Findik Y, Baykul T. Evaluation of Changes in Nasal Projection After Surgically Assisted Rapid Maxillary Expansion With 3dMD Face System. *J Craniofac Surg* 2020;31:e462-e465.
17. Lubbers HT, Medinger L, Kruse A, Gratz KW, Matthews F. Precision and accuracy of the 3dMD photogrammetric system in craniomaxillofacial application. *J Craniofac Surg* 2010;21:763–7.
18. Lee KW, Kim SH, Gil YC, Hu KS, Kim HJ. Validity and reliability of a structured-light 3D scanner and an ultrasound imaging system for measurements of facial skin thickness. *Clin Anat* 2017;30:878–86.
19. Kim SH, Jung WY, Seo YJ, Kim KA, Park KH, Park YG. Accuracy and precision of integumental linear dimensions in a three-dimensional facial imaging system. *Korean J Orthod* 2015;45:105–12.
20. Chu G, Zhao JM, Han MQ, Mou QN, Ji LL, Zhou H, et al. Three-dimensional prediction of nose morphology in Chinese young adults: a pilot study combining cone-beam computed tomography and 3dMD photogrammetry system. *Int J Legal Med* 2020;134:1803–16.
21. Xin P, Yu H, Cheng H, Shen S, Shen SG. Image fusion in craniofacial virtual reality modeling based on CT and 3dMD photogrammetry. *J Craniofac Surg* 2013;24:1573–6.
22. Kwon TG, Miloro M, Xi T, Han MD. Three-Dimensional Analysis of Lip Asymmetry and Occlusal Cant Change After Two-Jaw Surgery. *J Oral Maxillofac Surg* 2020;78:1356–65.
23. Lee SH, Kil TJ, Park KR, Kim BC, Kim JG, Piao Z, et al. Three-dimensional architectural and structural analysis—a transition in concept and design from Delaire's cephalometric analysis. *Int J Oral Maxillofac Surg* 2014;43:1154–60.
24. Zhao ZM, Zhu Y, Huo R, Su JR, Gao F. Three-dimensional cephalometric analysis of adolescents with cleft lip and palate using computed tomography-guided imaging. *J Craniofac Surg* 2014;25:1939–42.
25. Shrestha A, Song SH, Aung HN, Sangwatanakul J, Zhou N. Three-Dimensional Cephalometric Analysis: The Changes in Condylar Position Pre- and Post-Orthognathic Surgery With Skeletal Class III Malocclusion. *J Craniofac Surg* 2021;32:546–51.
26. Carey JC, Cohen MM, Jr., Curry CJ, Devriendt K, Holmes LB, Verloes A. Elements of morphology: standard terminology for the lips, mouth, and oral region. *Am J Med Genet A* 2009;149A:77–92.
27. Wu SQ, Pan BL, An Y, An JX, Chen LJ, Li D. Lip Morphology and Aesthetics: Study Review and Prospects in Plastic Surgery. *Aesthetic Plast Surg* 2019;43:637–43.
28. Batwa W, McDonald F, Cash A. Lip asymmetry and smile aesthetics. *Cleft Palate Craniofac J* 2013;50:e111-4.
29. Maal TJ, Plooi JM, Rangel FA, Mollemans W, Schutyser FA, Berge SJ. The accuracy of matching three-dimensional photographs with skin surfaces derived from cone-beam computed tomography.

30. Wong WW, Davis DG, Camp MC, Gupta SC. Contribution of lip proportions to facial aesthetics in different ethnicities: a three-dimensional analysis. *J Plast Reconstr Aesthet Surg* 2010;63:2032–9.
31. Metzger TE, Kula KS, Eckert GJ, Ghoneima AA. Orthodontic soft-tissue parameters: a comparison of cone-beam computed tomography and the 3dMD imaging system. *Am J Orthod Dentofacial Orthop* 2013;144:672–81.
32. Andrade LM, Rodrigues da Silva AMB, Magri LV, Rodrigues da Silva MAM. Repeatability Study of Angular and Linear Measurements on Facial Morphology Analysis by Means of Stereophotogrammetry. *J Craniofac Surg* 2017;28:1107–11.
33. Weinberg SM, Scott NM, Neiswanger K, Brandon CA, Marazita ML. Digital three-dimensional photogrammetry evaluation of anthropometric precision and accuracy using a Genex 3D camera system. *Cleft Palate Craniofac J* 2004;41:507–18.
34. Lubbers HT, Medinger L, Kruse AL, Gratz KW, Obwegeser JA, Matthews F. The influence of involuntary facial movements on craniofacial anthropometry: a survey using a three-dimensional photographic system. *Br J Oral Maxillofac Surg* 2012;50:171–5.

Figures

Figure 1

Soft tissue landmarks and measurement variables in CBCT model. A, landmarks: 1,Cm; 2,Sn; 3/4,Sbal-R/L; 5/6,Cph-R/L; 7,Ls; 8/9,Ch-R/L; 10,Li; 11,Stmo. B, length measurements: C/D, angular measurements.

Figure 2

Soft tissue landmarks and measurement variables in facial scanner. A, landmarks: 1,Cm; 2,Sn; 3/4,Sbal-R/L; 5/6,Cph-R/L; 7,Ls; 8/9,Ch-R/L; 10,Li; 11,Stmo. B, length measurements: C/D, angular measurements.

Figure 3

Bland-Altman plots showing the difference between the mean of linear measurements of CBCT and facial scanner in each variable. (a) length of philtrum crest on the left side. (b) length of philtrum crest on the right side. (c) width of mouth. (d) vermillion thickness of upper lip. (e) vermillion thickness of lower lip.

Figure 4

Bland-Altman plots showing the difference between the mean of angular measurements of CBCT and facial scanner in each variable. (f) protrusion angle of upper lip. (g) protrusion angle of lower lip. (h) angle of upper mouth on the left side. (i) angle of upper mouth on the right side. (j) angle of lower mouth on the left side. (k) angle of lower mouth on the right side.

Figure 5

Bland-Altman plots showing the difference between the mean of angular measurements of CBCT and facial scanner in each variable. (l) angle of Cupid's bow on the left side. (m) angle of Cupid's bow on the right side. (n) central angle of Cupid's bow. (o) nasolabial angle.