Original Article

The Accuracy and Precision of Twelve-angle Camera Facial Scan System for Measurement of Facial Soft Tissue

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Abstract

The 3-Dimension treatment planning using database from cone beam computed tomography and surface scan of patients' face could provide more information. However, the application of combined data is still limited. Few reports are available since the novel of twelve-angle camera facial scan system was introduced for maxillofacial application. Twenty-five healthy volunteers were included to study accuracy and precision of the novel twelve-angle camera facial scan system compared to digital Vernier caliper. Anthropometry points and distances were identified and measured using the digital Vernier caliper and novel twelve-angle camera facial scan system (H3 lumio3D, Bangkok, Thailand). Mean absolute deviation and Relative error magnitude were analyzed for indicated accuracy. The Intra Class Correlation and Dahlberg's error were analyzed for indicated precision. The accuracy from facial scan method demonstrated lower values than digital Vernier caliper method except left orbital fissure distance and intercanthal width. The excellence of precision was shown. The novel twelve-angle camera facial scan system demonstrated proper accuracy and precision due to these values were in a same range of previous systems. Nowadays, clinical applications of previous systems were reported. Twelve-angle camera facial scan system could be applied for clinical application too.

Keywords : 3D facial scan, anthropometry, digital vernier caliper, face, facial soft tissue, imaging, three-dimensional

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Introduction

Conventional two-dimension (2D) photo and lateral cephalogram are known as standard tools for planning, predicting and evaluating the hard and soft tissue for orthognathic surgery. 2D planning gives large amount of important data including the patient profile, facial skeletal, pre-operative treatment planning, or etc. However, the application for maxillofacial surgery are still limited due to several different protocol such as the distance between camera and subject, variation of camera angles, different head position (roll-pitch-yaw orientations) or inconsistent photography protocol, making it invalid and unreliable.[1-3] Due to these limitations, the third dimensional system is needed.

The new paradigm of orthognathic surgery planning are shifting from the conventional occlusion-centered planning to a soft tissue-based planning by using the combination of cone beam computed tomography (CBCT) and three-dimension (3D) facial scan so call three-dimension (3D) planning.[4] The advantage of 3D planning provides more information such as; guiding the treatment to the desired ultimate result, giving the patient a reasonable preview of the outcome and serving as a communication tool between orthodontist, surgeon and patient.[5]

Nowadays, the 3D facial scan is commonly used in several maxillofacial surgery such as creating the database of facial scan bank in order to replicate the similar structure or organ from the bank using as the template of tissue flap replacement at the avulsion area[6], predict outcomes before and after orthodontic and orthognathic treatment[7,8] or post-surgical evaluation and description of maxillofacial growth.[9]

Anthropometry is the biological science of human body measurement, Farkas 1994, introduced various measurement landmarks and distances of the face.[10] Since then, many anthropometric data were used and applied for various purposes including; forensic science, physical variation, or paleoanthropology, etc.[11] A number of database of craniofacial anthropometry measurement were created in order to be used as a standard for surgeons to compare the pre- and post-surgery.[8] There are several conventional and digital anthropometry measurements of facial soft tissue such as; direct manual anthropometry, digitizer (digital Vernier caliper), 3D Computed tomography (3DCT), 3D scanner, DI3D (digital facial scan system). All of these 3D facial soft tissue analysis show favorable accuracy and reproducibility and they can be used in clinical practice and research studies.[9]

Recently, novel 3D facial scan system, containing both pentagonal and hexagonal light-emitting diode (LED) panels for continuous illumination and twelve-angle cameras in several panels known as H3 lumio3D (Lumio 3D corporation, Bangkok, Thailand) is available. (Fig. 1)

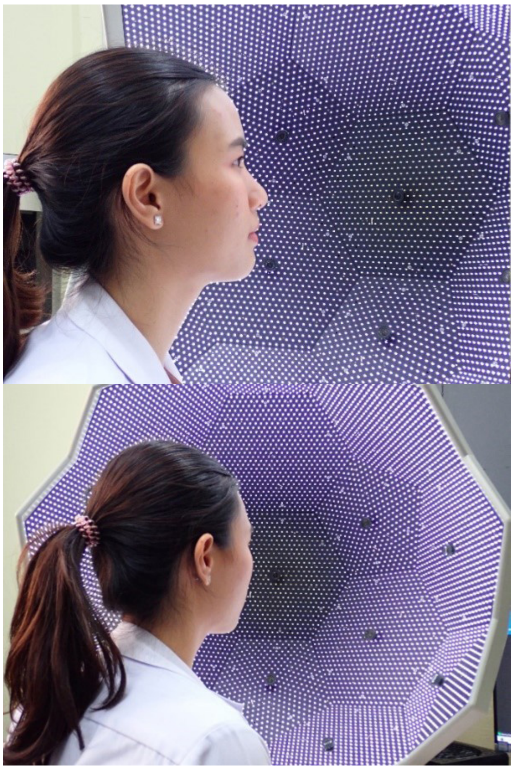

Figure 1 *A twelve-angle camera facial scan system (H3 Lumio3d, Bangkok, Thailand)*

This system can take a 3D facial scan with 96 frames in less than a second and stores into its software. The 3D image is constructed from these frames. Build-in software and several stereolithography files have a compatibility to open these 3D images in order to determine an interesting point, measure the distance and angle. (Fig. 2)

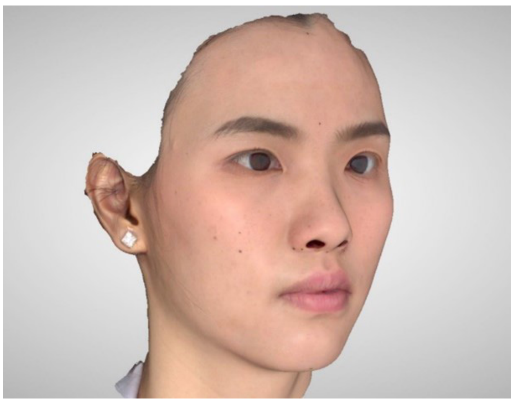

Figure 2 *The 3D image from the twelve-angle camera facial scan system (H3 Lumio3d) in stereolithography (STL) file format*

The aim of this study was to investigate the accuracy and precision of the novel twelve-angle camera facial scan system compared to the digital Vernier caliper method of human facial Anthropometry for clinical application.

Materials and methods

Sample size calculation

G*power software (version 3.1.9.2) was used for sample size calculation from previous facial scan system of Kim SH[12]. The estimation of sample size was based on 5 % type I error and 80 % study power. From the calculation, the sample size for each group was twenty-five subjects. Twenty-five healthy volunteers were included in this study. The subjects who had previous history of head or facial trauma, pathology,orthognathic surgery, congenital deformity were excluded from this study.

All measurements were performed by one examiner. The Anthropometry points were marked with cosmetic color pen. These points were cleaned by cosmetic cleansing kits after examination.

Ethical considerations

This research was approved by the ethical committee of the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand (HREC-DCU 2019-079). All data related to the patients were kept in confidentiality throughout the study.

Referent points and distances

The most common Anthropometry points for orthognathic surgery were used and shown in Table1,

Table 1 *The list and abbreviation of Anthropometry pointsa*

Anthropometry points	Definition
Trichion (Tr)	The end point of hair line
Glabella (Ga)	The middle point of supraorbital ridge
Endocanthion (EnL, EnR)	The innermost point of eye commissure (left and right sides)
Exocanthion (ExL, ExR)	The outermost point of eye commissure (left and right sides)
Alare (AlL, AlR)	The lateral most point of alar contour (left and right sides)b
Alare contour (AcL, AcR)	The lowest point of alar base (left and right sides)
Subnasale (Sn)	The midpoint of columella
Cheilion (ChL, ChR)	The outermost point of vermillion border (left and right sides)
Stomion (Sto)	The middle contact point of upper and lower lipsc
Menton (Me)	The inferior most point of chin

[a] *These Anthropometry points were adapted from several papers[10,12,13]*

[b] *In this study, AlL and AlR were projected to alar base level and provide the same width of left Alare to right Alare, prevent the distortion from digital Vernier caliper's beak and easier to mark the points.*

[c] *In this study, the lowest point of upper lip was used for incompetent lip subjects as in the study of Stomion (Sto).*

The measurements of distance between Anthropometry of interest were upper facial height (Tr-Ga), middle facial height (Ga-Sn), lower facial height (Sn-Me), orbital fissures (ExL-EnL, EnR-ExR), intercanthal width (EnL-EnR), alar base width (AcL-AcR), mouth fissure (ChL-ChR), upper lip length (Sn-Sto), and lower lip length (Sto-Me) (Fig. 3).

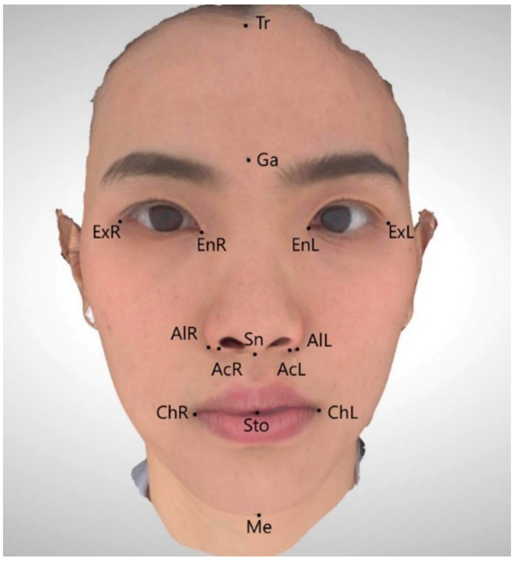

Figure 3 *Landmark of Anthropometry points. These points are valuable in several applications and surgical treatment planning. (Trichion (Tr), Glabella (Ga), Endocanthion (EnL, EnR), Exocanthion (ExL, ExR), Alare (AlL, AlR)[a], Alare contour (AcL, AcR), Subnasale (Sn), Cheilion (ChL, ChR), Stomion (Sto), Menton (Me)). [a]In this study, AlL and AlR were projected to alar base level and provide the same width of left Alare to right Alare, prevent the distortion from digital Vernier caliper's beak and easier to mark the points.*

Measurement technique

The measurement in this study were performed using two methods; digital Vernier caliper method and facial scan method.

1. Digital Vernier caliper method

The distant between the Anthropometry points were measured using digital Vernier caliper twice. The mean value was used for analysis.

2. Facial scan method

The facial scan was performed by using Twelve-angle camera facial scan system (H3 Lumio3d, Bangkok, Thailand). All reference points were selected on the build-in software and the distance between the Anthropometry points were measured and calculated by Euclidean method (Straight line method) in millimeter.

The mean value, accuracy (mean absolute deviation, MAD), REM (Relative error magnitude (REM)) and precision (Dahlberg's error) in 1/10 millimeter of the distance from the two methods were calculated. The values were compared to investigate a correlation between the two methods by Intraclass correlation coefficient (ICC).

Calibration tests

1. Calibration with an expert

One examiner and an expert performed two methods of measurement, using two subjects whom would not be included in this study. Agreement of Anthropometry points were calibrated to improve validity of methods before beginning the study. Data were analyzed by intraclass correlation coefficient (ICC).

2. Self-calibration

One examiner performed a self-calibration in order to provide a validity of both methods before beginning the experiment. Five volunteers (Whom were not included in this study) were recruited for calibration (two repeat measurements for both methods within two weeks). Data were analyzed using intraclass correlation coefficient (ICC).

2.6 Statistical analysis

The accuracy of both methods was performed using Mean absolute deviation (MAD) and Relative error magnitude (REM, estimate of error magnitude) as shown in the following equation. The smaller value implies a more accuracy.

$$Mean\ absolute\ deviation\ (MAD) = \frac{\sum_{i=1}^{n}|x_i - \bar{x}|}{n}$$

$$Relative\ error\ magnitude\ (REM) = \frac{MAD}{\bar{x}} \cdot 100\%$$

Intraclass correlation coefficient (ICC) was used for analysis of reliability index or precision.[14] It is a modification from Pearson correlation Coefficient, described by Fisher.[15] ICC has been widely used in conservative care medicine to evaluate interrater, test-retest, and interrater reliability. The result of calculation was reported in a range between 0 and 1, with the results closer to 1 having a higher precision. The data were analyzed using compare mean statistics by SPSS version 22.0 (SPSS, Inc., Chicago IL).

The other precision value of both methods was performed using a Dahlberg's error. The smaller value implies a more precision.[16]

$$Dahlberg's\ error^2 = \frac{Error\ of\ the\ first\ measure + Error\ of\ the\ second\ measure}{2}$$

$$Dahlberg's\ error^2 = \frac{({}_1^1x - {}_1^2x)^2 + \cdots + ({}_n^1x - {}_n^2x)^2}{2n}$$

$$Dahlberg's\ error = \sqrt{\frac{\sum_{i=1}^{n} {d_i}^2}{2n}}$$

When d_i is the difference between the first and the second measurement. n is the sample size which was re-measured.

Results

Intra-observer and Inter-observer validity

Intraclass correlation coefficient (ICC) of digital Vernier caliper method and facial scan method were 0.984 and 0.984, while ICC between examiner and expert of digital Vernier caliper method and facial scan method were 0.996 and 0.998, respectively. As the results of two correlation coefficients indicated that examiner had enough validity to perform the study.

Demographic data

The twenty-five volunteers were recruited to the study. Mean age was 25.8 ± 3.6 years (22 to 34 years old) while male and female ratio was 1:1.08.

Accuracy

All MAD and REM from facial scan method showed lower values than digital Vernier caliper method except left orbital fissure distance. (Table 2)

Table 2 *Results of accuracy test. All MAD and REM from facial scan method showed lower values than digital Vernier caliper method except left orbital fissure distance*

Distances	AVERAGE (mm)		MAD (mm)		Difference of MAD	REM (%)	
	Conventional	Facial Scan	Conventional	Facial Scan		Conventional	Facial Scan
Upper facial height (Tr-Ga)	55.724	54.698	0.355	0.122	0.233	0.637	0.222
Middle facial height (Ga-Sn)	65.219	66.597	0.327	0.125	0.202	0.501	0.188
Lower facial height (Sn-Me)	68.329	69.381	0.405	0.102	0.303	0.593	0.147
Orbital fissure L (ExL-EnL)	38.641	37.089	0.458	0.518	-0.060	1.186	1.396
Orbital fissure R (ExR-EnR)	38.104	36.523	0.477	0.391	0.086	1.251	1.072
Intercanthal width (EnL-EnR)	34.311	35.296	0.309	0.275	0.034	0.900	0.778
Alar width (AlL-AlR)	35.720	38.125	0.456	0.106	0.350	1.277	0.279
Alar base width (AcL-AcR)	28.483	30.257	0.400	0.120	0.280	1.405	0.398
Mouth fissure (ChL-ChR)	48.975	50.750	0.515	0.287	0.228	1.052	0.565
Upper lip length (Sn-Sto)	22.555	22.927	0.257	0.160	0.097	1.138	0.696
Lower lip length (Sto-Me)	42.593	43.439	0.287	0.190	0.097	0.674	0.438

Precision

Eleven distance measurements of maxillofacial Anthropometry points were reported in Table1. Intraclass correlation coefficients of all measurements were in the range from 0.817 to 0.990, indicating an excellent precision between the two methods. (Table 3)

Table 3 *Intraclass correlation coefficients between digital Vernier caliper method and facial scan method. Intraclass correlation coefficients of all measurements ranged from 0.817 to 0.990, indicating the excellent precision between the two methods*

Distances	Intraclass Correlation	95% interval (border)	
		Lower Bound	Upper Bound
Upper facial height (Tr - Ga)	0.974	0.954	0.985
Middle facial height (Ga - Sn)	0.978	0.962	0.988
Lower facial height (Sn - Me)	0.990	0.983	0.994
Orbital fissures L (ExL-EnL)	0.817	0.678	0.896
Orbital fissures R (EnR-ExR)	0.832	0.704	0.905
Intercanthal width (EnL-EnR)	0.958	0.926	0.976
Alar width (AlL-AlR)	0.936	0.887	0.964
Alar base width (AcL-AcR)	0.943	0.899	0.967
Mouth fissure (ChL - ChR)	0.916	0.853	0.953
Upper lip length (Sn - Sto)	0.962	0.933	0.978
Lower lip length (Sto - Me)	0.974	0.953	0.985

The Dahlberg's error of facial scan method was lesser than digital Vernier caliper method except left orbital fissure distance and Intercanthal width. (Table 4)

Table 4 *Results of precision test. Dahlberg's error of facial scan method was lesser than digital Vernier caliper method except left orbital fissure distance and Intercanthal width*

Distances	Dahlberg's error (1/10 millimeter)	
	Conventional	Facial Scan
Upper facial height (Tr-Ga)	0.826	0.232
Middle facial height (Ga-Sn)	0.591	0.222
Lower facial height (Sn-Me)	0.708	0.177
Orbital fissure L (ExL-EnL)	0.814	0.937
Orbital fissure R (ExR-EnR)	0.850	0.772
Intercanthal width (EnL-EnR)	0.503	0.511
Alar width (AlL-AlR)	1.623	0.204
Alar base width (AcL-AcR)	1.384	0.279
Mouth fissure (ChL-ChR)	0.857	0.491
Upper lip length (Sn-Sto)	0.472	0.289
Lower lip length (Sto-Me)	0.530	0.357

Discussion

Twelve-angle camera facial scan system was shown to have better mean absolute deviation (MAD) results when compared with digital Vernier caliper. The overall average of MAD from facial scan method was 0.217 mm (0.102 to 0.518). This value is lower than that of Kim SH *et al.* who reported an average MAD of Morpheus 3D® scanner (Morpheus Co., Seoul, Korea) at 0.75 mm.[12] and the study by Zhao YJ *et al.* which demonstrated an accuracy of 3dMd (3dMD Inc., Atlanta, GA, USA) at 0.58±0.11 mm and Face scan (Isravision, Darmstadt, GER) at 0.57±0.07 mm.[17] De Menezes *et al.* reported the accuracy (MAD) of Vectra 3D (Canfield Scientific, Inc., USA) to be lower than 0.25 mm.[13] Moreover, De Menezes *et al.* described higher accuracy (lower MAD) was observed when the Anthropometry points were obviously detected, while unmarked distance such as mouth fissure demonstrated lower accuracy than others. Nowadays, the clinical application of these three commercial systems were reported.[18-20] Thus, the accuracy of H3 Lumio3D should be adequate in term of clinical application due to accuracy (MAD) is in a range of previous systems.

Based on the result of the precision test using intraclass correlation coefficient test (ICC), the distance between Anthropometry points can be classified into three groups which are excellent, moderate and clinical acceptable. The excellent group demonstrated the ICC above 0.93. The reason behind this highly precision is because the Anthropometry points are clearly identified, then the measurement was accurately performed. Those Anthropometry points are Upper facial height (Tr - Ga), Middle facial height (Ga - Sn), Lower facial height (Sn - Me), Intercanthal width (EnL-EnR), Alar width (AlL-AlR), Alar base width (AcL-AcR), Upper lip length (Sn - Sto), Lower lip length (Sto - Me). (Table 5)

Table 5 *Three groups of precision (classified by intraclass correlation coefficient (ICC))*

Clinical acceptable (0.817 – 0.832)	Moderate (0.916)	Excellent (higher than 0.93)
Orbital fissures L(ExL-EnL)	Mouth fissure (ChL-ChR)	Upper facial height (Tr - Ga)
Orbital fissures R (EnR-ExR)		Middle facial height (Ga - Sn)
		Lower facial height (Sn-Me)
		Intercanthal width (EnL-EnR)
		Alar width (AlL-AlR)
		Alar base width (AcL-AcR)
		Upper lip length (Sn - Sto)
		Lower lip length (Sto - Me)

Mouth fissure (ChL-ChR) are classified in the moderate group, because of the minor mismatch of the measured points (unmarkable anthropometry position to prevent the toxicity of eyeliner pen ingestion). However, Cheilion are obviously noticed for measurement.

The Anthropometry points and distances in the clinical acceptable group are Orbital fissures L (ExL-EnL) and Orbital fissures R (EnR-ExR). The difficult measurements in this group are ambiguous points (Exocanthion), because of hard to discrete skin color, depth of surface and unmarkable points (prevent intoxication from eyeliner pen to the eyes)

Our data were similar to the study by Amornvit *et al.*[21] They described the difficulty of capturing by handheld facial scan and iphone X. The high accuracy and simplicity of capturing were at forehead, cheek and chin, while the medium were at earlobe and eyelids and the hardest were located at teeth, extra auditory canal and nostril.

The mean of another precision value (Dahlberg's error) was 0.332 mm (0.177 to 0.937 mm) which is close to the precision values of Vectra 3D (< 0.7 mm)[17] and Morpheus 3D scanner (<0.5 mm).[12]

The facial scan can be performed within a second. The results can be repeatable and comparable. These advantages are suitable for children subjects, sensitive area of face such as orbital area, alar, and neurological patients who cannot co-operate in conventional measurements.

We also found minor limitations of the twelve-angle camera facial scan system. Black objects such as hidden spot in nostrils, deep nasolabial fold close to the nose and hair may distort the 3D facial file. On preauricular area and upper face in long-hair women may have a distortion from hair line, side burns and slippage of hair.

Conclusion

Within the limitation of the study, The novel twelve-angle camera facial scan system demonstrated proper accuracy and precision due to these values being in a range of previous facial scan systems. Nowadays, clinical applications of previous systems were reported. Twelve-angle camera facial scan system could be applied for clinical application.

Conflict of interest

All authors declare that they have no conflicts of interest relevant to this article.

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