Use of a Three-dimensional Smartphone Scanner in

by Kartika P. Sari

Use of a Three-dimensional Smartphone Scanner in the Quantitative Analysis of Repaired Unilateral Cleft Lip during the Coronavirus Disease Pandemic

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Background: Cleft lip, a major craniofacial abnormality, is highly prevalent among people with low socioeconomic status in Indonesia. Direct two-dimensional measurement of the affected region is the gold standard for surgical preparation; however, its compliance and usability are limited in pediatric patients. Modern smartphones, including iPhones, are equipped with high-resolution cameras, which can record images and videos of a face. Here, we investigated whether a three-dimensional (3D) smartphone scanner can be used for the facial measurements of patients with unilateral cleft lip.

Methods: Twelve facial measurements were acquired after cleft lip surgery in three female and seven male patients (aged 11–29 months) with unilateral cleft lip using direct anthropometry and a 3D smartphone scanner. The accuracy and precision of the 3D smartphone scanner were assessed through comparative analyses (t test and Bland–Altman plot).

Results: The anthropometric data obtained using the 3D smartphone scanner matched the direct measurement data. The linear measurements did not differ significantly between two-dimensional and 3D modalities ($P > 0.05$). The intraobserver reliabilities of the two-dimensional smartphone scanner of the first and second observers were high (intraclass correlation coefficient 0.876–0.993 and Cronbach alpha 0.920–0.998) and moderate to high (intraclass correlation coefficient 0.839–0.996 and Cronbach alpha 0.940–0.996), respectively. Inter-observer data showed an intraclass correlation coefficient of 0.876–0.981 and a Cronbach α of 0.960–0.997.

Conclusion: The 3D smartphone scanner is effective, efficient, economical, quick, and feasible for facial measurements of patients with unilateral cleft lip and is a viable alternative to direct two-dimensional measurements. *(Plast Reconstr Surg Glob Open 2023; 11:e4895; doi: 10.1097/GOX.0000000000004895; Published online 29 March 2023.)*

INTRODUCTION

Cleft lip and palate are major craniofacial anomalies and are mostly reported in populations with low socioeconomic status in Indonesia.[1] The incidence of cleft lip is two per 1000 live births in Indonesia.[2] In Indonesia, we have developed our own surgical repair method known as the Djhonsjah method, which is a modification of the traditional Millard rotation-advancement lip repair in which the flap is coupled to a vermillion muscle lateral flap for the repair of cleft lip.[3] Primary correction of cleft lip deformity aims to restore the balance between function and proper anatomy and to achieve long-term symmetry.[1] Anthropometric measurements showed symmetrical nose improvement after primary correction using a systematic strategy for unilateral cleft nose abnormalities.[4]

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Fig. 1. The direct anthropometry by using caliper was performed in children, with the help of parents and toys.

standard deviation, and mean difference. Comparative analyses between the two methods (direct measurement and 3D) were performed using a Bland–Altman plot and paired t test. Differences were considered statistically significant at a P value less than 0.05. The precision of the 3D smartphone scanner was assessed, and measurements were performed by two different observers. We tested the intra- and inter-observer reliabilities. We used the interclass correlation coefficient (ICC) and Cronbach α to test the reproducibility of these landmark measurements using the 3D smartphone scanner. An ICC of more than 0.5 and a Cronbach α of more than 0.7 were considered reliable.

Time Interval for Each Session

The total time required for each measurement session was determined using a stopwatch. Data were processed using SPSS version 16 and compared using a paired t test. Results with P less than 0.05 were considered statistically significant.

RESULTS

The study population comprised male and female patients at a ratio of 2.3:1. All patients were aged between 11 and 29 months. Left-sided cleft was dominant (4:1) in
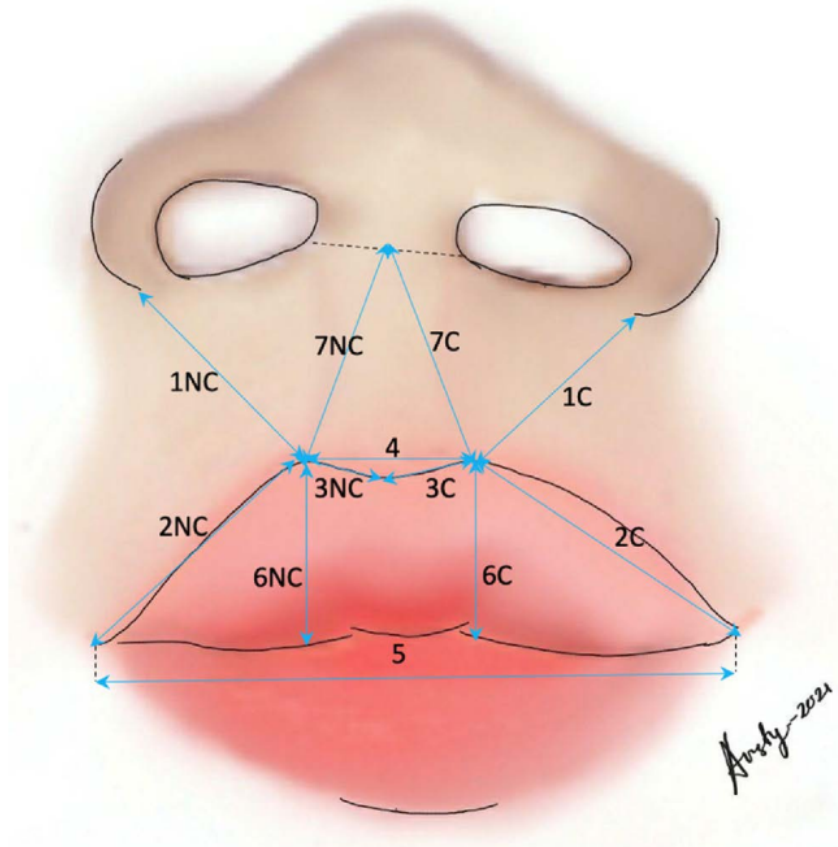
Fig. 2. The 12 anthropometric anatomic landmarks for unilateral cleft anthropometry, determined by us.
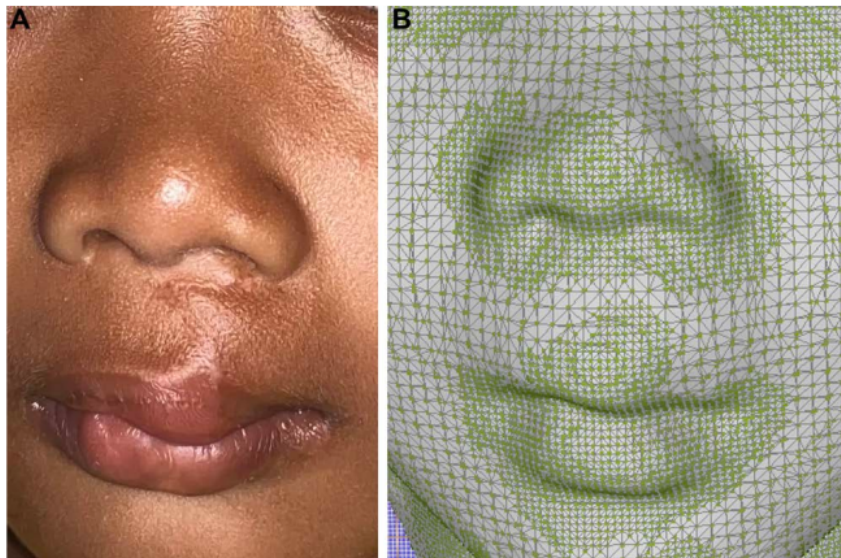
Fig. 3. Results obtained with the smartphone scanner. A, Three-dimensional smartphone scan showing results of application scanning using free iPhone operating system software. B, Three-dimensional smartphone scan showing acquired data being processed in Meshlab software on a computer.

the patients. The results obtained with the smartphone scanner are shown in Figure 3. All observers tested negative in the COVID-19 polymerase chain reaction test.

Scanning Time

The mean time from scanning until measurement was 7.33 ± 1.41 min.

3D Smartphone Scanner Accuracy

A reasonable agreement was evident between the 2D and 3D measurements. The Bland–Altman plot values were between the measures of agreement (-4.830 to 5.310). There were no significant differences in the linear measurements between the 2D and 3D measurements ($P > 0.05$). The mean difference was in the range of 0.35–1.57 mm. The highest difference was observed in

the horizontal lip length on the noncleft side (1.57 mm; Table 1).

Intra- and Interobserver Reliabilities of the 3D Smartphone Scanner for Precision

The intraobserver reliability and validity of the first observer were 0.876–0.993 with ICC and 0.920–0.998 with Cronbach α, and those of the second observer were 0.839–0.996 with ICC and 0.940–0.996 with Cronbach α (Table 2). The inter-observer reliability and validity were 0.876–0.981 with ICC and 0.960–0.997 with Cronbach α (Table 3).

DISCUSSION

Anthropometric measurements can be obtained using direct or indirect methods. Direct anthropometry

Table 1. Paired *t* Test Comparing Linear Measurements between the Direct (2D) Method and the Indirect (3D) Smartphone Scanner Method

Variable (Mean ± SD)	2D	3D	Mean Difference	P
Lip vertical height cleft	10.40 ± 2.09	10.90 ± 2.04	0.5	0.590
Lip vertical height noncleft	11.20 ± 2.29	11.71 ± 2.40	0.51	0.634
Lip horizontal length cleft	16.81 ± 2.87	17.31 ± 2.97	0.5	0.709
Lip horizontal length noncleft	17.28 ± 2.89	18.85 ± 2.88	1.57	0.664
Peak cupid's bow to midpoint cleft	5.05 ± 1.24	5.89 ± 1.46	0.84	0.182
Peak cupid's bow to midpoint noncleft	3.90 ± 1.21	4.70 ± 1.37	0.8	0.185
Cupid's bow width	7.66 ± 1.58	7.74 ± 1.70	0.08	0.920
Lip width	33.25 ± 1.43	33.78 ± 1.49	0.53	0.423
Cupid's bow vermillion width cleft	7.46 ± 1.98	8.07 ± 2.05	0.61	0.508
Cupid's bow vermillion width noncleft	7.03 ± 1.68	7.39 ± 1.71	0.36	0.639
Midline columellar crease to cupid's bow cleft	10.06 ± 1.50	10.53 ± 1.66	0.47	0.522
Midline columellar crease to cupid's bow noncleft	10.13 ± 1.85	10.48 ± 1.96	0.35	0.687

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Table 2. Intraobserver Statistical Analysis of the Three-dimensional Smartphone Scanner Measurements

Variable	Observer 1		Observer 2	
	ICC	Cronbach α	ICC	Cronbach α
Lip vertical height cleft	0.936	0.978	0.979	0.993
Lip vertical height noncleft	0.928	0.975	0.900	0.990
Lip horizontal length cleft	0.992	0.997	0.996	0.996
Lip horizontal length noncleft	0.993	0.998	0.994	0.994
Peak cupid's bow to midpoint cleft	0.876	0.920	0.967	0.989
Peak cupid's bow to midpoint noncleft	0.916	0.970	0.839	0.940
Cupid's bow width	0.987	0.939	0.996	0.979
Lip width	0.961	0.987	0.969	0.990
Cupid's bow vermillion width cleft	0.986	0.995	0.976	0.992
Cupid's bow vermillion width noncleft	0.978	0.992	0.964	0.988
Midline columellar crease to cupid's bow cleft	0.985	0.995	0.987	0.995
Midline columellar crease to cupid's bow noncleft	0.988	0.996	0.982	0.994

Table 3. Interobserver Statistical Analysis of the Three-dimensional Smartphone Scanner Measurements

Variable	Cronbach α	Interclass Correlation Coefficient
Lip vertical height cleft	0.989	0.940
Lip vertical height noncleft	0.995	0.973
Lip horizontal length cleft	0.997	0.981
Lip horizontal length noncleft	0.995	0.972
Peak cupid's bow to midpoint cleft	0.977	0.878
Peak cupid's bow to midpoint cleft noncleft	0.977	0.876
Cupid's bow width	0.975	0.951
Lip width	0.960	0.922
Cupid's bow vermillion width cleft	0.997	0.980
Cupid's bow vermillion width noncleft	0.992	0.954
Midline columellar crease to cupid bow cleft	0.987	0.926
Midline columellar crease to cupid bow noncleft	0.994	0.963

is the gold standard, but it requires patient experience and cooperation.[6] Digital imaging helps understand the mathematical symmetry and architecture of the lips. Linear measurements of the lip height and width are used to assess symmetry. Aesthetic improvements are objectively evaluated by comparing the proportions of unoperated and operated lips.[7] Conventional photography is prone to errors, and direct anthropometry is impractical for daily use.[8] Djohansjah Cleft Lip surgical method was applied without measurement preoperatively. It trained plastic surgical residents to be more meticulous in creating symmetrical lips between cleft and noncleft.[3]

Smartphones have been applied to plastic surgery for improved communication, ease of data collection and storage, education, and postoperative monitoring.[9] Currently, the most popular smartphone operating systems are iOS, by Apple, and Android, which is open source. Modern smartphones, such as iPhones, are equipped with high-resolution cameras, which can record images and videos of the user's face. In iPhone generation X, Apple was the first to introduce a 3D scanner. The scanner, which uses a patented scanning method involving structured light called, the True Depth System, is used for 3D face authentication and recognition by the Face ID system. This involves exact registration of facial data captured from 30,000 points, which are recorded via infrared

camera with a refresh rate of 60 Hz and processed by the neural engine of the smartphone chip. Apple itself does not specify the accuracy of the relevant technologies or hardware.[10]

The 3D scanning technology has evolved to be inexpensive, accurate, and easy to use. 3D face scanning has wide applications in medicine and dentistry, and also in capturing facial emotions.[11] Mobile applications provide better accuracy in scanning results. Numerous 3D scanning applications are available online, for example, on the Apple store. Mobile applications improve the performance and scanning results of smartphones.[12,13] Scandy Pro provides images closest to the real face in terms of similarity. It is also better in process performance and smoothness. Scandy Pro requires 35 seconds to complete facial scanning and processing. It offers one free scan per day and paid memberships at 1.99 Euros weekly, 5.99 Euros monthly, and 49.99 Euros annually.[12,13] Dzelzkalēja et al assessed four mobile apps for 3D face scanning and showed, based on visual evaluation, that the most accurate 3D models for human faces were developed by Scandy Pro. The other applications such as Heges 3D scanner, Bellus 3D Face Application, 3D Scan Anything, Trnio 3D Scanner, and 3D Scanner Pro had given inferior results when applied on human male and female models.[12,13]

In our current study, we observed a mean difference of 0.35–1.57 mm when compared with direct anthropometry.

In another study, the accuracy using an iPhone as a three-dimensional scanner has been published by Rudy et al.[14] The iPhone was found to be accurate and precise to within 0.5 mm when compared with a commonly used, validated, and expensive three-dimensional Canfield Vectra H1 camera.[14] Knoops et al investigated the precision of the Structure Sensor (Occipital Inc, Boulder, Colo.) and M4D Scanner (Rodin 4D, Merignac, France) and reported root mean square errors of 0.5±0.04 mm and 0.51±0.03 mm.[15]

The learning process of 3D point tracing and experience in recognizing 3D landmarks are essential benchmarks in ensuring the accuracy and precision of 3D measurements.[16] The results of the 3D scanning measurements are user-dependent, in line with those of previously reported studies that involved anthropometric measurements using stereophotogrammetric devices. Furthermore, expensive devices rely on manual marking protocols in measurement software, and their use requires extensive training.[17] Tse et al used three raters to perform indirect anthropometry in 26 consecutive patients with unrepaired unilateral cleft lip ± palate. This study tested the reliability of nasolabial anthropometric measurements using three-dimensional stereophotogrammetry. The mean differences for nose and lip measurements were less than 1 mm and between 0.8 mm and 1.3 mm[18]; these values were similar to those obtained in our study.

The 3D scanning data obtained using smartphones are an alternative to routine documentation in patients with a preoperative cleft lip. The data are helpful for surgical planning and teaching reconstruction and animation for trainee plastic surgeons on the proviso that routine measurements are undertaken before and after surgery for proper evaluation.

The 3D scanning anthropometry method used in this study reduces both patient–doctor contact during the pandemic and a child's procedural fear, owing to noncontact with calipers. The application and software used in this study are accessible, user-friendly, and recommended for lower- and middle-income countries, such as Indonesia. No such study in patients with unilateral cleft lip has been reported during the COVID-19 pandemic. Our study indicates that the 3D smartphone single-center scanner is a welcomed technology with potential in medical quantitative analysis.

This study was limited by its small sample and design. Further multicenter studies with larger samples are warranted in the future. The study results are limited to the data on postoperative results because of our surgical method, which does not use any preoperative measurements. The number of observers was limited by rule of minimal contact between patient and physician, which was caused by the COVID-19 pandemic. The 3D smartphone scanner technology can be applied in other cases of craniofacial surgery, such as hemifacial microsomia, Parry–Romberg syndrome, and facial cleft. Measurements can be elaborated further to include linear and volumetric measurements.

The 3D smartphone scanner can perform anthropometric measurements in patients with cleft lip accurately. It is more effective, efficient, and economical;

faster; and easier to apply than 2D measurement systems. Volumetric measurement is another approach that can be used besides linear measurement to perform a more accurate analysis of facial anatomy in the preoperative or postoperative settings. 3D smartphone scanning can also be applied to other craniofacial abnormalities where measurements are required, such as hemifacial microsomia and facial cleft. Mobile applications such as Scandy Pro require practice and skill to obtain the best results.

CONCLUSIONS

The 3D smartphone scanner is accurate and precise. It can be applied in patients with unilateral cleft lip and other conditions that require quantitative analysis. Our study revealed that the 3D smartphone scanner is efficient, cost-effective, and suitable for facial measurement during the COVID-19 pandemic. The 3D smartphone scanner shows potential for application in medical quantitative analysis.

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PATIENT CONSENT
The patients (or parents or guardians of patients) provided written consent for the use of their images.

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