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Original Research Article

3D morphometric comparison between two different facial scanning systems: An in vivo study

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Abstract

Background: Soft tissue analysis is the crux in surgical treatment planning. With notable advancements in Artificial intelligence (AI) and augmented reality and a paradigm shift to digital dentistry, it is of paramount importance to check the reproducibility of different scanners for a best-fit alignment. This study aims to compare and assess the reliability of two facial scanning systems.

Aim: To compare morphometric 3D measurements obtained from facial scans by Kodak CareStream CS 9600 and Bellus 3D face scan.

Materials and Methods: Facial scans were obtained from 20 Indian subjects aged 18-35 years via CareStream CS facial scanner and Bellus 3D facial scanning app. Nine linear facial morphometric parameters were measured, compared, and analyzed using MeshLab software developed by ISTI (Italian National Research Council) in Rome, Italy. These measurements were subsequently superimposed using the same MeshLab software. The statistical analysis of the data was performed using IBM SPSS software. Independent paired t-tests were employed to investigate inter-group comparisons, Intra-Class Coefficient (ICC) was used to evaluate measurement reproducibility, and Kappa statistics were utilized to assess intra-observer reliability.

Results: There was no significant difference in any of the linear 3D morphometric measurements between the groups, suggesting that both Bellus 3D and CareStream facial scans showed good and comparable scanning accuracy (p value > 0.05). The ICC score between the readings were all above 0.80, corresponding to excellent reproducibility of the measurements. A kappa statistic of 0.78, used to assess intra-observer reliability, indicated a strong level of agreement between the readings.

Conclusion: The conclusion drawn from the results of this study was that the accuracy of 3D images obtained from Carestream and Bellus3D exhibited strong and similar scanning repeatability.

Keywords: Facially-driven orthodontics, CBCT, face scan, Smart-phone based sensors, Bellus 3D

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1. Introduction

In recent years, there has been a pronounced uptick in the adoption of three-dimensional (3D) imaging modalities within the medical field, particularly in disciplines such as orthodontics and maxillofacial surgery. These advanced techniques are pivotal for examining dentoskeletal relationships, assessing general facial esthetics, and scrutinizing the morphology of hard and soft tissues in orthodontic practice.[1,2] In the dental field, there has been a recent shift towards a digital era, propelled by substantial advancements in optical scanning and design technologies. This evolution from 2D to three-dimensional (3D) technology has fundamentally disrupted conventional treatment approaches.[3,4] Instrumental 3D analysis has undergone substantial evolution, originating with the advent of computed tomography in 1972 and advancing to contemporary, high-precision 3D laser scanning methodologies.[5] Facial landmarks extracted through 3D face scanning technology can be digitally captured using specialized scanners. These landmarks serve various purposes and literature reports their several clinical applications including facial recognition, emotion capture, planning for orthognathic surgery, and rehabilitation in maxillofacial procedures.[6,7] Recent investigations have underscored the burgeoning significance of 3D facial scanners within the field of dentistry, citing their remarkable precision and high degree of accuracy.[8] Breakthroughs in 3D facial analysis have catalyzed the emergence of non-invasive

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techniques that exploit optical properties and digital algorithms, particularly in the sphere of 3D facial scanning technologies.[9,10]

The routine implementation of 3D diagnostic workflows is anticipated soon, but the expensive nature of high-end facial scanners is hindering this progress. Numerous professional dental applications assert their reliability and accuracy; however, their clinical precision has been met with skepticism and remains controversial.[11] Cone Beam Computed Tomography (CBCT) is a three-dimensional (3D) imaging modality that delivers low-distortion and highly accurate craniofacial images, surpassing conventional imaging methods. Upon processing the volumetric data, CBCT produces 3D panoramic and cephalometric visuals.[12,13] However, CBCT has notable limitations. Predominantly utilized in dental care for imaging the hard tissues of the orofacial region, its efficacy in soft tissue visualization is constrained by inadequate contrast resolution and texture differentiation, thus limiting its application in soft tissue analysis.[14] To address the paucity of soft tissue visualization in CBCT imaging, contemporary digital workflows have integrated sophisticated 3D facial scanners. These scanners utilize non-ionizing modalities such as stereophotogrammetric analysis, structured-light interferometry, and laser profilometry to produce intricate three-dimensional representations of facial soft tissue. This approach effectively captures the nuances of texture and static geometry, crucial for precise orthodontic treatment planning.[15]

In contemporary orthodontics, the combination of smartphones and artificial intelligence has become a prevalent practice. AI, manifested through dental monitoring software, utilizes patients' smartphones for routine scanning. This technique presents notable benefits in the context of the pandemic and facilitates self-assessment coaching telehealth solutions.[16] The burgeoning field of 3D face scanning holds vast potential across various domains of medicine and dentistry, encompassing applications such as facial biometrics, emotion analysis, preoperative planning for aesthetic surgery, and rehabilitation in maxillofacial treatments. Advancements in smartphone and tablet technology, featuring LiDAR and TrueDepth capabilities, are driving innovation in this area.[17,18]

Therefore, this investigation sought to compare and scrutinize the precision and repeatability of facial scans captured by two disparate systems: the CareStream CS 9600 facial scanner and the Bellus 3D facial scan app.

2. Materials and Methods

This in vivo study centered on 3D facial scans obtained from a cohort of 20 individuals seeking treatment at the Department of Orthodontics and Dentofacial Orthopedics at Saveetha Dental College in Chennai. Approval for the study protocol was granted by the Institutional Review Board of SIMATS Deemed University, and was assigned the ethics approval number IHEC/SDC/ORTHO-2104/23/111.

Sample size estimation using G*Power analysis software (Version 3.0.10, Kiel, Germany) was performed with an alpha level of 0.05 and a power of 0.90, referencing previous work by Pelliteri et al.[19] This determined a required sample size of 10 subjects per group. Inclusion criteria specified Dravidian individuals aged 18-35 years who had completed their growth phase. Exclusion criteria included males with facial hair, as well as subjects with facial scars, prior cosmetic facial procedures, or noticeable dermatological irregularities.

The evaluation encompassed the Bellus 3D facial scan application and the CareStream CS 9600 facial scanner. The Bellus 3D Dental Pro app leverages the TrueDepth camera found in iOS 12.2 and newer Apple devices like the iPad Pro and iPhone X to perform rapid 3D facial scans. This process efficiently captures the subject's facial structure in 15 seconds, gathering measurements from multiple perspectives. During the scanning procedure, each participant was asked to securely hold the phone using their dominant hand to ensure consistent dental arch occlusion. The app autonomously adjusted the distance between the phone and the subject, as well as the accurate tilt of the head.

The second scan utilized the Kodak CareStream CS 9600 scanner. Participants were seated in a chair with backrest, maintaining a standardized distance from the scanner throughout. The operator meticulously oriented the subject towards the scanner camera, with images displayed on a computer screen for precise alignment verification. Five static facial scans were captured with occluded dental arches, comprising a frontal view, one from each lateral aspect, and two from the left and right 3/4 profile orientations. Technicians carefully aligned reference markers on these scans, which were then amalgamated into a cohesive 3D scan through software processing.

A total of 9 linear measurements were calibrated using the following reference cephalometric landmarks that were marked on the subject's face using micropore tape and a marker: Trachion (T-marked as 1), Glabella (G- 2), Soft tissue Nasion (Na_{ST-} 3), right and left endocanthion (RD, LD- 4), right and left exocanthion (LE, RE- 5), Zygomatic prominence (Zy- 6), right and left lateral alar wall (Al- 7), Pronasale (Pn- 8), soft tissue Pogonion (Pog_{ST}- 9), , right and left lip commissures (RLC, LLC- 10) (**Figure 1**). The parameters assessed were total facial height, bizygomatic width, intercanthal distance, distance from outer canthus-outer canthus on the contralateral side, distance from $Nasion_{ST}$- Pronasale, width of the nose, height of the nose, inter-commissure lip distance and Pronasale $_{ST}$- Pogonion $_{ST}$ (**Figure 2**). Each participant was seated in a chair equipped with a stabilizing backrest designed to prevent any inadvertent movement of the head and torso, thereby maintaining their natural head posture consistently (**Figure 1**).

2.1. Digital measurements

The OBJ file of each subjects' 3D reconstructed faces were imported into a reverse engineering software, MeshLab software (ISTI [Italian National Research Council], Rome, Italy). Therefore, the virtual points were obtained by inter landmark digital distances for intergroup comparison. Operator (HN) measured each value three times to check for intra-observer reliability.

To assess the proportion of surface areas corresponding between the two scans for each subject, the MeshLab software was utilized. This tool automatically aligned the scans based on predetermined reference points as shown in **Figure 2**, and measured the percentage of surface overlap within designated tolerance thresholds, depicted in Figure 3, as described the study by Pelliteri et al.[19]

1. 0 +/- 0.5mm - highly reproducible
2. +/- 0.5 mm to +/- 1mm - moderately reproducible
3. +/- 1.5 mm to +/- 1mm- poorly reproducible
4. 1.5 mm, < -1.5 mm- not reproducible

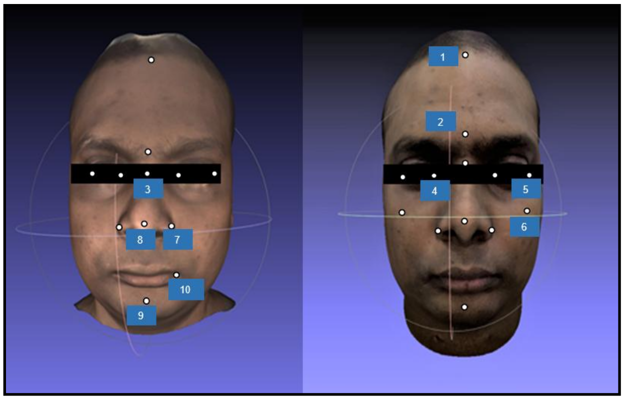

Figure 1: Facial scans (from left to right) as taken from CareStream CS scanner and Bellus 3D app respectively

Figure 2: Soft tissue volume facial scans (from left to right) as taken from Care Stream CS scanner and Bellus 3D app respectively

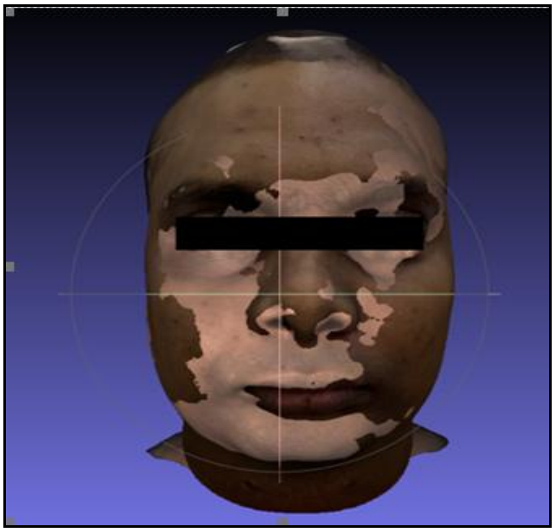

Figure 3: Superimposition of the two scans based on best-fit alignment of the reference points

3. Statistical Analysis

Statistical analysis was performed using SPSS V17 Statistics (Software version 20.0 for Windows). Normality of the collected data was assessed with the Shapiro-Wilk test. Initial descriptive statistics were computed for parametric data, including mean, standard deviation, and standard error of inter-landmark distances. An Independent paired t-test was utilized for inter-group comparisons. Kappa statistics was employed to assess the Intra-observer reliability. The intraclass correlation coefficient (ICC), with a threshold exceeding 0.9, indicated the consistency and reproducibility of measurements. The level of significance (p-value) was set at less than 0.05.

4. Results

The present study recruited a total 20 subjects, adhering to the inclusion criteria of this study (11 males and 9 females), with all subjects falling under 18-35 years of age. The mean age for subjects in Group I (Bellus 3D scan) was 23.50 +/- 3.114 years and that of Group II (CareStream scan) was 24.20 +/- 3.372 years respectively. Kappa statistics indicated a reliability score of 0.80, signifying substantial agreement in intra-observer assessments. The ICC scores consistently surpassed 0.80, demonstrating good reproducibility of the measurements. There was no statistically significant difference in gender distribution between the two groups (p-value = 0.502), mentioned in **Table 1.** There were no discernible variations in the linear 3D morphometric measurements between the groups, implying that both Bellus 3D and CareStream facial scans demonstrated robust and comparable accuracy in scanning (p value > 0.05), as mentioned in **Table 2**.

Table 1: Gender distribution among the study groups

Group	**Gender N (%)**		**Chi-square value (χ 2)**	***p* value**
	Male	**Female**	0.450	0.502
Bellus 3D	6 (60)	4 (40)		
CareStream	5 (50)	5 (50)		

Table 2: Inter-group comparison for digital facial measurements

Sr. No	**Parameter**	**Group**	**N**	**Mean**	**Standard Deviation**	***p* value**
1	Face Height	Bellus 3D	20	112.71	14.15	0.540
		CareStream		107.46	10.12	
2	Bizygomatic width	Bellus 3D	20	104.96	8.77	0.910
		CareStream		104.67	10.01	
3	Medial Intercanthal Distance	Bellus 3D	20	34.35	2.50	0.926
		CareStream		32.79	2.72	
4	Lateral Intercanthal Distance	Bellus 3D	20	88.74	7.31	0.525
		CareStream		90.26	6.49	
5	St. Nasion-Pronasale	Bellus 3D	20	44.22	4.08	0.081
		CareStream		43.49	2.94	
6	St Pronasale- St Pogonion	Bellus 3D		79.64	12.63	0.812
		CareStream		75.25	9.34	
7	Width of nose	Bellus 3D	20	38.10	7.12	0.500
		CareStream		36.12	5.38	
8	Width of lip	Bellus 3D	20	55.36	1.56	0.225
		CareStream		51.01	4.23	
9	Height of nose	Bellus 3D	20	27.88	4.56	0.476
		CareStream		27.06	3.01	

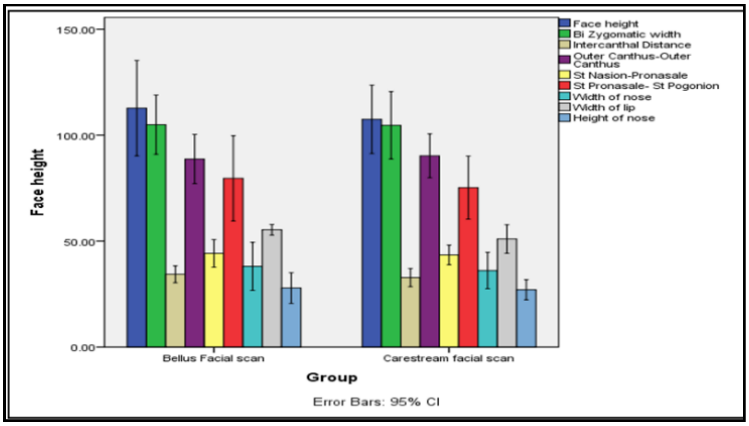

Figure 4: Graphical representation of morphometric measurements (with error bars) between the groups

5. Discussion

The emergence of facially guided orthodontics, propelled by economically feasible and non-intrusive facial scanning technologies, will align with the advancing capabilities of ubiquitous facial scanners integrated into mobile devices like smartphones and tablets. While these technologies exhibit adequate sophistication for macro-level facial evaluations, ensuring the precision and reliability of scanned models is pivotal prior to endorsing facial scanning as a standardized tool for clinical diagnosis and assessment.[20,21]

In this regard, the results of this study yielded that the linear morphometric measurements from Bellus 3D facial scan app were accurate and comparable, and revealed no statistically significant difference when compared to facial scans taken from CareStream CS facial scanner. The results revealed no statistically and clinically significant differences between any of the linear morphometric facial measurements between the two scanner systems. These findings were substantiated by the results from the study by Hajeer et al., which highlighted seven cephalometric points, including nasion, proven to be consistently reproducible when superimposing two scans of the same subject.[2] The research findings indicated that the nasion consistently showed reproducibility, maintaining a standard deviation consistently below 0.5 mm. It remained stable as a reliable cephalometric landmark over time and post-maxillofacial surgery. In contrast, Aung et al. reported lower reliability in measurements involving the trichion.[20] Located at the hairline, the trichion serves as a cephalometric landmark that presents technical challenges for scanners, often leading to ambiguous images and potential inaccuracies in measurement outcomes.[20]

The analysis of superimpositions revealed variability in reproducibility across different facial areas. The right and left cheeks exhibited the most extensive average surface coverage in the highly reproducible category, reaching approximately 70%. These findings were supported by Eidson et al., who aligned facial scans on stable regions such as the intercanthal area, nasal dorsum, temporal region, and upper zygomatic zones. They reported minimal differences between the two images, averaging only 0.14 mm in these regions.[8] Contrary to initial assumptions, the forehead area exhibited low reproducibility across most subjects, supported by findings by Aung et al.[20]

In this study, CBCT scans served as the standard reference, despite their limitations in evaluating 3D facial soft tissues. Stereophotogrammetry should have been prioritized as the primary method for assessing the accuracy of facial images captured using True Depth technology on smartphones. The 3D scans acquired using Bellus3D Pro through smartphones consistently exhibited reliable outcomes. A recent study by D'Ettorre et al. highlighted that when comparing surface-to-surface deviation between Bellus3D and 3dMD (stereophotogrammetry), there was an overlap of about 80.01% within a discrepancy range of 1 mm.[22] In a systematic review conducted by Quinzi et al., which centered on stereophotogrammetry and smartphone technology, it was determined that "Fixed stereophotogrammetry systems exhibited mean accuracies spanning from 0.087 to 0.860 mm, portable stereophotogrammetry scanners from 0.150 to 0.849 mm, and smartphones from 0.460 to 1.400 mm."[23] Errors in volumetric estimation often reveal more pronounced discrepancies in smartphone scanning compared to photogrammetry techniques.[24]

Regarding head positioning, the authors underscored the crucial need to maintain consistent posture during scanning. Variations in posture can induce contraction or relaxation of soft tissues, potentially causing notable changes in facial morphology. Ensuring correct posture, which is a stringent requirement of the face-scanning protocol, resulted in facial scans with discrepancies in the submillimeter range. This study reports good repeatability of the scans. An identified limitation of this study is the initially small sample size, coupled with an uneven gender distribution favoring women. Literature suggests that differences, particularly noticeable in the orbital area, could be attributed to variations between closed and open eyelids. While CBCT scans typically feature closed eyes, TrueDepth scans capture images with open eyes, potentially impacting the study findings.

A critical consideration in this discourse is the advantage of the TrueDepth scanner found on Apple smartphones or tablets, which offers cost-effectiveness and widespread availability. Scans can be swiftly conducted with real-time processing, avoiding the need for patient exposure to radiation. Furthermore, this technology presents new prospects for telemedicine applications within dental practices.

6. Conclusion

There were no statistically significant variations observed in the linear morphometric measurements between the CareStream CS 9600 and Bellus 3D facial scanning systems. Both scanners exhibited robust and comparable repeatability in capturing accurate 3D photogrammetric data. Future research should prioritize assessing the effectiveness of facial scanners as diagnostic tools for monitoring prolonged soft tissue healing in patients undergoing orthognathic surgery.

7. Source of Funding

None.

8. Conflict of Interest

None.

References

1. Hajeer MY, Millett DT, Ayoub AF, Siebert JP. Applications of 3D imaging in orthodontics: part I. *J Orthod.* 2004;31(1):62–70. DOI: 10.1179/146531204225011346.
2. Hajeer MY, Ayoub AF, Millett DT, Bock M, Siebert JP. Three-dimensional imaging in orthognathic surgery: the clinical application of a new method. *Int J Adult Orthodon Orthognath Surg.* 2002;17(4):318–30. DOI: 10.1179/146531204225011346.
3. Berssenbrügge P, Berlin NF, Kebeck G, Runte C, Jung S, Kleinheinz J. et al. 2D and 3D analysis methods of facial asymmetry in comparison. *J Craniomaxillofac Surg.* 2014 Sep;42(6):e327–34. DOI: 10.1016/j.jcms.2014.01.028
4. Toma AM, Zhurov A, Playle R, Ong E, Richmond S. Reproducibility of facial soft tissue landmarks on 3D laser-scanned facial images. *Orthod Craniofac Res.* 2009;12(1):33–42. DOI: 10.1111/j.1601-6343.2008.01435.x
5. Coward TJ, Watson RM, Scott BJ. Laser scanning for the identification of repeatable landmarks of the ears and face. *Br J Plast Surg.* 1997;50(5):308–14. DOI: 10.1016/s0007-1226(97)90538-5
6. Lee JG, Jung SJ, Lee HJ, Seo JH, Choi YJ, Bae HS. et al. Quantitative anatomical analysis of facial expression using a 3D motion capture system: Application to cosmetic surgery and facial recognition technology. *Clin Anat.* 2015;28(6):735–44. DOI: 10.1002/ca.22542.
7. Huang YH, Seelaus R, Zhao L, Patel PK, Cohen M. Virtual surgical planning and 3D printing in prosthetic orbital reconstruction with percutaneous implants: a technical case report. *Int Med Case Rep J.* 2016;9:341–5. DOI: 10.2147/IMCRJ.S118139
8. Eidson L, Cevidanes LHS, de Paula LK, Hershey HG, Welch G, Rossouw PE. Three-dimensional evaluation of changes in lip position from before to after orthodontic appliance removal. *Am J*

Orthod Dentofacial Orthop. 2012;142(3):410–8.DOI: 10.1016/j.ajodo.2012.01.018

9. Tsunori M, Mashita M, Kasai K. Relationship between facial types and tooth and bone characteristics of the mandible obtained by CT scanning. *Angle Orthod.* 1998;68(6):557–62. DOI: 10.1043/0003-3219(1998)068<0557:RBFTAT>2.3.CO;2
10. Bianchi SD, Spada MC, Bianchi L, Verze L, Vezzetti E, Tornincasa S. et al. Evaluation of scanning parameters for a surface colour laser scanner. *Int Congr Ser.* 2004; 1268:1162–7. DOI:10.1016/j.ics.2004.03.264
11. Tomášik J, Zsoldos M, Oravcová Ľ, Lifková M, Pavleová G, Strunga M, et al. AI and Face-Driven Orthodontics: A Scoping Review of Digital Advances in Diagnosis and Treatment Planning. AI. 2024;5(1):158–76. https://doi.org/10.3390/ai5010009
12. Ezhov M, Gusarev M, Golitsyna M, Yates JM, Kushnerev E, Tamimi D. et al. Clinically applicable artificial intelligence system for dental diagnosis with CBCT. *Sci Rep.* 2021;11(1):15006. DOI: 10.1038/s41598-021-94093-9.
13. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am. 2008;52(4):707–30. DOI: 10.1016/j.cden.2008.05.005.
14. Jain S, Choudhary K, Nagi R, Shukla S, Kaur N, Grover D. New evolution of cone-beam computed tomography in dentistry: Combining digital technologies. *Imag Sci Dent*. 2019;49(3):179–90. DOI: 10.5624/isd.2019.49.3.179.
15. Shujaat S, Bornstein MM, Price JB, Jacobs R. Integration of imaging modalities in digital dental workflows - possibilities, limitations, and potential future developments. Dentomaxillofac Radiol. 2021;50(7):20210268. DOI: 10.1259/dmfr.20210268
16. Thurzo A, Kurilová V, Varga I. Artificial Intelligence in Orthodontic Smart Application for Treatment Coaching and Its Impact on Clinical Performance of Patients Monitored with AI-TeleHealth System. Healthcare (Basel). 2021;9(12). Available from: http://dx.doi.org/10.3390/healthcare9121695
17. Amornvit P, Sanohkan S. The Accuracy of Digital Face Scans Obtained from 3D Scanners: An In Vitro Study. *Int J Environ Res Public Health*. 2019;16(24): http://dx.doi.org/10.3390/ijerph16245061
18. Alisha KH, Batra P, Raghavan S, Sharma K, Talwar A. A New Frame for Orienting Infants With Cleft Lip and Palate During 3-Dimensional Facial Scanning. *Cleft Palate Craniofac J.* 2022;59(7):946–50. DOI: 10.1177/10556656211028512.
19. Pellitteri F, Brucculeri L, Spedicato GA, Siciliani G, Lombardo L. Comparison of the accuracy of digital face scans obtained by two different scanners. *Angle Orthod.* 2021;91(5):641–9. DOI: 10.2319/092720-823.1
20. Aung SC, Ngim RC, Lee ST. Evaluation of the laser scanner as a surface measuring tool and its accuracy compared with direct facial anthropometric measurements. *Br J Plast Surg.* 1995;48(8):551–8. DOI: 10.1016/0007-1226(95)90043-8.
21. Othman SA, Ahmad R, Mericant AF, Jamaludin M. Reproducibility of facial soft tissue landmarks on facial images captured on a 3D camera. *Aust Orthod J.* 2013;29(1):58–65.
22. D'Ettorre G, Farronato M, Candida E, Quinzi V, Grippaudo C. A comparison between stereophotogrammetry and smartphone structured light technology for three-dimensional face scanning. *Angle Orthod*. 2022;92(3):358–63. DOI: 10.2319/040921-290.1.
23. Quinzi V, Polizzi A, Ronsivalle V, Santonocito S, Conforte C, Manenti RJ. et al. Facial Scanning Accuracy with Stereophotogrammetry and Smartphone Technology in Children: A Systematic Review. *Children.* 2022;9(9):1390. http://dx.doi.org/10.3390/children9091390
24. Saif W, Alshibani A. Smartphone-Based Photogrammetry Assessment in Comparison with a Compact Camera for Construction Management Applications. *NATO Adv Sci Inst Ser E Appl Sci.* 2022;12(3):1053. DOI:10.3390/app12031053.

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