Vectra H2® stereophotogrammetry system evaluation for 3D facial analysis in children

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Background: Facial anthropometric analysis is a valuable tool for assessing growth and development in children. It allows for continuous patient monitoring, facilitates the identification of morphological variations and asymmetries, supports diagnostic processes, contributes to the planning and predictability of therapeutic interventions, and aids in evaluating treatment outcomes. This study aimed to evaluate Vectra H2® stereophotogrammetry system for facial anthropometry analysis in children.

Methods: Thirty participants were selected, ranging from 5 to 12 years old. Prior to the acquisition of facial images, nineteen anatomical landmarks were marked with a black eyeliner pen on the participants' faces, so that 14 linear measurements could be quantified. The three-dimensional (3D) image of the facial surface was captured using the stereophotogrammetry equipment. First, linear measurements were quantified directly on the participant's face using a digital caliper. In the second phase of the anthropometric analysis, the same linear measurements were taken on the 3D image using stereophotogrammetry system software. Intraclass correlation coefficient (ICC) test was applied to evaluate intra- and inter-examiner errors. For data analysis, Pearson's and Spearman's correlation coefficient tests were applied. The mean absolute difference (MAD) was used to describe the differences. Data were presented as mean/standard deviation and median/interquartile deviation.

Results: All 14 facial measurements showed statistically significant difference ($P<0.05$). The measurements Tr-G, G-Pn, G-Sn, Ene-Che, and End-Chd demonstrated very strong correlation (r values between 0.9485 and 0.9026), while Ald-Ale, Exe-Che, Sn-Ls, Sn-Pg, Ls-Li, Exd-Chd, and Chd-Che measurements exhibited strong correlation (r values between 0.8821 and 0.7094). Acd-Ace and Cphe-Cphd measurements showed moderate correlation ($r=0.5790$ and $r=0.6982$). The measurements Sn-Ls and Ene-Che presented a lower

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MAD value (0.53), and the measurements Ald-Ale showed the highest value (5.38).

Conclusions: Vectra H2® facial stereophotogrammetry system proved to be a validated and reliable method for facial anthropometry analysis in children.

Keywords: Imaging; three-dimensional (3D); child; validation study

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Introduction

In children, craniofacial development is a highly coordinated process involving multiple anatomical structures that must grow in synchrony to achieve harmonious morphology (1). Alterations in craniofacial growth can occur at any stage during the developmental phase and may negatively impact the overall process. A thorough understanding of craniofacial growth and development in childhood is essential for enabling timely and effective early interventions (2).

Facial anthropometric analysis is a valuable tool for assessing growth and development in children. It enables continuous patient monitoring, facilitates the identification of morphological variations and asymmetries, supports diagnostic processes, contributes to the planning and predictability of therapeutic interventions, and aids in evaluating treatment outcomes (3-6). Researchers traditionally perform facial anthropometry using direct measurements with a digital caliper, which is considered the gold standard. However, they are gradually replacing digital calipers by photogrammetry systems (4,5,7). Drawbacks of the digital caliper method include its reliance on patient cooperation and the time required to perform measurements. Furthermore, it prevents the collection of additional data once the patient is no longer present, thereby limiting the scope of craniofacial assessment (3).

The stereophotogrammetry system uses high-resolution cameras to quickly capture images of individuals from different angles and reconstruct them into a three-dimensional (3D) image. This system is equipped with software that enables visualization and analysis of images through linear, angular, and volumetric morphological measurements (4,6,8). This technology facilitates indirect anthropometry, reducing physical contact and thereby minimizing the risk of injury. It provides a comprehensive image of the facial surface, ensuring an accurate representation of skin texture and color (8,9). Additionally, it allows for future craniofacial measurements (3). This approach is safe, non-invasive, sustainable, and accurate (2).

3D facial imaging systems have continued to advance, resulting in a range of options that include both static and portable devices (4,6). Static devices are more expensive, bulky, and require frequent calibration, but they can capture multiple facial images simultaneously (5). In contrast, portable devices (such as those using a single-lens reflex camera and a computer system) are more affordable and do not require calibration. However, they must capture three images of the same individual from different angles within a short time frame (5,6).

Several 3D imaging systems have previously demonstrated high accuracy and repeatability for facial analysis (3-6,10). However, literature lacks studies evaluating its use in children. Due to the distinct morphological and behavioral characteristics of pediatric populations compared to adults, this study is critical for addressing a notable gap in the current scientific literature. Thus, this present study aimed to evaluate Vectra H2® stereophotogrammetry system for facial anthropometry analysis in children. The specific objective was to compare facial linear measurements obtained using a digital caliper with those from 3D facial images analyzed through stereophotogrammetry software. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-2025-243/rc).

Methods

Experimental design

This study was approved by the Institutional Review Board of Bauru School of Dentistry, University of São Paulo (Certificate of Presentation for Ethical Assessment: 64546422.4.0000.5417), as well as full agreement with the Declaration of Helsinki and its subsequent amendments. For the inclusion criteria, children of both genders, aged

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Figure 1 Image acquisition. (A) Marking of anatomical points. (B) Front image capture. (C) Side image capture. This image is published with the patient/participant's legal guardians consent.

Table 1 Definition of anatomical reference points

Anatomic points	Definition
Tr	On the hairline in the middle of the forehead
G	Most prominent point on the midline between eyebrows
Pn	The most prominent point on the tip of the nose
Ex	Point on the lateral corner of the eye (right and left)
En	Point on the inner corner of the eye (right and left)
Al	Most prominent point on the nasal wing (right and left)
Ac	Most lateral point on the nasal wing (right and left)
Sn	Midpoint on the base of the columella where the lower border of the nasal septum meets the upper lip
Cph	Junction between upper lip vermillion and philtral peak on the right and left
Ls	Midpoint on upper lip redness
Li	Midpoint on lower lip redness
Ch	Point on the lip commissure (right and left)
Pg	The most anterior point on the chin in the midline

Ac, alar curvature; Al, alar base; Ch, lip commissure; Cph, crista philtri; En, endocanthus; Ex, exocanthus; G, glabella; Li, lower lip; Ls, upper lip; Pg, pogonium; Pn, nasal tip; Sn, subnasal; Tr, trichion.

between 5 and 12 years, were selected for the study. Participants who had craniofacial syndrome or anomaly, who had experienced trauma on the face, who wore glasses and refused to remove them, and/or those who had 3D images of the face with poor quality were excluded from the sample. Participation in the study took place upon the signing of the informed consent form by the legal guardians and the assent form by the participants.

Sample size was defined using a pilot study using paired *t*-test. Considering the standard deviation of 3.87 mm of the Tr-G length, minimum relevant change of 1 mm, 0.05 of significance level, and 0.80 of test power, this cross-sectional observational study would be conducted with at least 30 participants.

3D image acquisition

The acquisition of the 3D image of the facial surface was performed using Vectra H2 portable stereophotogrammetry equipment (Canfield Scientific Inc., Parsippany, NJ, USA). The markings of the anatomical landmarks were made with a black fine-tipped eye liner pen (Make B, O Boticário, São José dos Pinhais, PR, Brazil) (*Figure 1A*). The reference points and linear measures applied were used following a previous study (11) (*Tables 1,2*). Photographs were taken in a quiet, well-lit setting with volunteers standing on a reference mat to ensure consistency. Participants wore caps to cover their hair, kept a neutral expression, looked at a fixed point, lightly touched their lips together, and positioned their heads with the Frankfurt plane parallel to the ground (12). The operator conducted three consecutive photographic captures within a short timeframe: the first with the camera positioned at a 45-degree angle to the patient's right, the second from a frontal perspective

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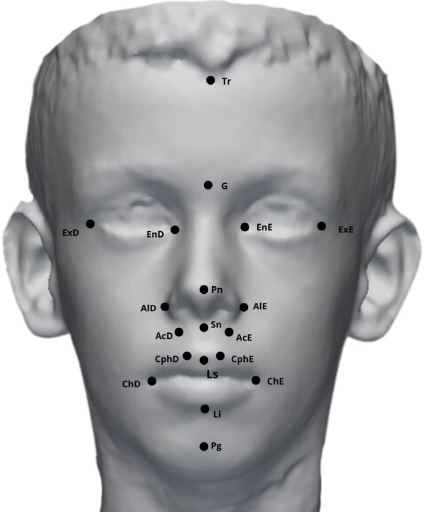

Figure 2 Anatomical points.

Table 2 Definition of linear measurements

Linear measurements	Definition
Tr-G	Length between the trichion and the glabella
G-Pn	Length between the glabella and the tip of the nose
G-Sn	Length between the glabella and subnasal
Sn-Ls	Upper lip skin length
Sn-Pg	Length between subnasal and pogonium
Ls-Li	Length of upper and lower lip redness
ExD-ChD	Distance between exocanthus and right labial commissure
ExE-ChE	Distance between exocanthus and left labial commissure
EnD-ChD	Distance between endocanthus and right labial commissure
EnE-EnE	Distance between endocanthus and left labial commissure
AlD-AlE	Nasal width
AcD-AcE	Width of the wing curvature
CphD-CphE	Right and left crista philtri
ChD-ChE	Lip width

(*Figure 1B*), and the third at a 45-degree angle to the patient's left. One visual laser projected by the equipment indicates the recommended distance (*Figure 1C*). Before the acquisition of facial images, 19 anatomical reference points (*Table 1*, *Figure 2*) were made in each participant so that 14 linear measurements could be quantified (*Table 2*, *Figure 3*).

Analysis of anthropometric measurements

The first stage of the linear measurement analysis was performed immediately after image capture, using a digital caliper (model 100.174BL, Digimess, São Paulo, SP, Brazil; accuracy 0.003 mm). A trained and calibrated examiner performed the quantification of the linear measurements directly on each participant's face. At the end of the clinical consultation, the markings were removed with a makeup remover wipe (Make B, O Boticário). In the second stage, for the digital anthropometric assessment, the same examiner evaluated the linear measurements on the 3D images (file format. tom) using the stereophotogrammetry system software (Mirror Medical Imaging software, Canfield Scientific Inc.). All linear measurements were quantified in mm. In this study, to ensure the reliability and calibration of the examiner (A1), a second experienced examiner (A2) was assessed one-third of the sample (10 participants), allowing for the performance of reliability testing (11).

Statistical analysis

Statistical tests were conducted using Jamovi software (version 2.3.28), with a significance level set at 5%. The statistical analysis followed the methodology described in previous publications (6,11). To assess intra- and inter-examiner errors, both examiners evaluated one-third of the total sample twice, with a 15-day interval between assessments (11). The selected cases were randomly chosen using an online randomization tool. The data were analyzed using the intraclass correlation coefficient (ICC). To assess normality, the Shapiro-Wilk test was applied. For data with a normal distribution, Pearson's correlation coefficient was used, and for data with a non-normal distribution, Spearman's correlation coefficient was used. The mean absolute difference (MAD) was utilized to describe the differences. Data were presented as mean/standard

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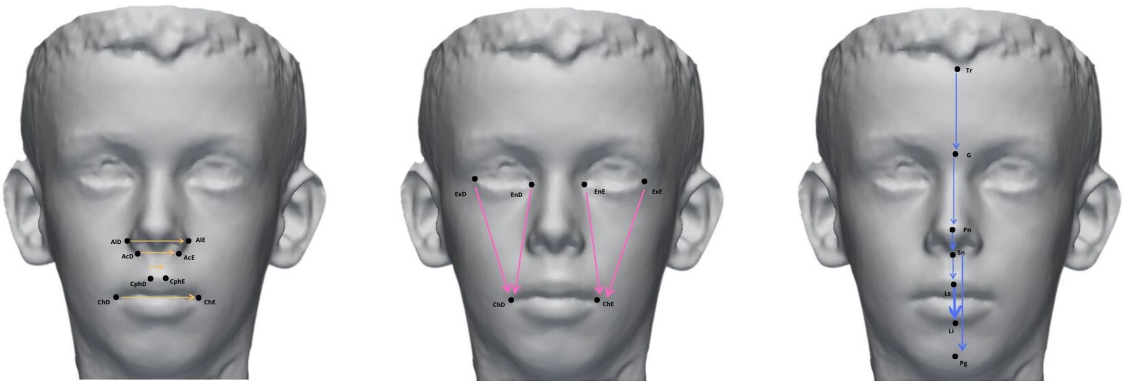

Figure 3 Linear measurements. Yellow lines indicate horizontal (transverse) linear measurements. They primarily focus on the width of features in the middle and lower face, such as nasal width (connecting AlD-AlE and AcD-AcE), philtrum width (CphD-CphE), and oral/mouth width (ChD-ChE). Pink lines represent diagonal linear measurements. They connect specific points around the eyes (ExD, EnD, EnE, ExE) to the corners of the mouth (ChD, ChE). Such measurements are typically used to assess facial proportions and potential asymmetries. This continuous blue line indicates multiple vertical linear measurements along the facial midline. It connects a series of landmarks from the forehead (Tr) down to the chin (Pg), allowing for the quantification of different facial heights and vertical segments (G-Pn, Pn-Sn, Sn-Ls, Ls-Li, Li-Pg).

deviation and median/interquartile deviation.

Results

Facial measurements and images were collected from 37 children, following the application of exclusion criteria. Data analysis was conducted on a final sample of 30 participants. The faces of 30 participants were analyzed, including 12 females and 18 males. The mean age of the participants was 7.50 years old.

Intra-examiner analysis of both examiners A1 and A2 showed very strong correlation (examiner A1: r=0.988; and examiner A2: r=0.995). Inter-examiner analysis exhibited very strong correlation (r=0.993).

All 14 facial measurements showed correlation. The measurements Tr-G, G-Pn, G-Sn, Ene-Che, and End-Chd demonstrated very strong correlation (r values between 0.9485 and 0.9026), while Ald-Ale, Exe-Che, Sn-Ls, Sn-Pg, Ls-Li, Exd-Chd, and Chd-Che measurements exhibited strong correlation (r values between 0.8821 and 0.7094). Acd-Ace and Cphe-Cphd measurements showed moderate correlation (r=0.5790 and r=0.6982, respectively) (*Table 3*).

Regarding the MAD, the measures Sn-Ls (0.53), Sn-Pg (0.57), Ls-Li (0.62), Ene-Che (0.53), End-Chd (0.68), obtained the lowest values. The measures Exd-Chd (1.71), Acd-Ace (1.35), Cphe-Cphd (1.03), G-Pn (2.24), G-Sn (2.44) presented regular values. The measures Tr-G (3.67), Chd-Che (3.83), Exe-Che (4.44), Ald-Ale (5.38) obtained the highest values.

Discussion

The present study has recruited 30 participants. This number is consistent with that found in the literature, ranging from 10 to 60 individuals (3,5,8-11,13,14). Although previous studies have explored facial analysis using stereophotogrammetry devices in children (11), this population presents behavioral characteristics that can compromise optimal image acquisition. Factors such as postural and facial changes between successive captures, as well as involuntary movements, may introduce errors in the final 3D reconstruction (4). Given these challenges, this study aimed to validate, for the first time, the use of a stereophotogrammetry device specifically in a pediatric population. Children in the age range of this study tend to make body and facial movements between measurements, which compromises the standardization of facial positioning. Stereophotogrammetry capture is performed within a short time interval, which promotes the child's cooperation in remaining still during the procedure. This condition may explain why measurements in regions with greater movement during facial expressions (Ald-Ale, Exe-Che, Sn-Ls, Sn-Pg, Ls-Li, Exd-Chd, Chd-Che, Acd-

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Table 3 Accuracy analysis of facial measurements obtained with a digital caliper and by the stereophotogrammetry software (Pearson's correlation coefficient and Spearman's correlation coefficient)

Measurement	Caliper, mean/SD or (median/IA)	Software, mean/SD or (median/IA)	Correlation, r	MAD
Tr-G	51.58/9.05	51.85/8.77	0.9485	3.67
G-Pn	43.38/4.18	44.49/4.17	0.9343	2.24
G-Sn	50.27/4.22	52.71/4.20	0.9388	2.44
Sn-Ls	11.65/1.95	12.49/1.66	0.7094	0.53
SN-PG	44.48/4.72	46.31/5.00	0.7832	0.57
Ls-Li	16.77/3.18	17.67/2.75	0.772	0.62
Exd-Chd	59.99/5.24	62.80/3.52	0.7729	1.71
Chd-Che	40.08/3.07	41.99/3.49	0.7471	3.83
Exe-Che	(59.35/7.55)	(61.82/5.31)	0.8345†	4.44
Ene-Che	55.6/4.71	56.43/3.42	0.9102	0.53
End-Chd	55.42/4.64	56.94/3.79	0.9026	0.68
Ald-Ale	28.19/2.80	33.09/3.07	0.8821	5.38
Acd-Ace	17.82/2.58	18.53/2.16	0.5790	1.35
Cphe-Cphd	10.01/2.04	12.25/1.85	0.6982	1.03

Mean, SD, median, IA, MAD were expressed in millimeters. †, Spearman's correlation coefficient. IA, interquartile amplitude; MAD, mean absolute difference; SD, standard deviation.

Ace and Cphe-Cphd) showed lower levels of agreement compared to measurements obtained in more static regions of the face (Tr-G, G-Pn, G-Sn, Ene-Che, and End-Chd).

The stereophotogrammetry system was assessed by comparing 23 distances between 11 reference points, using a digital caliper (9). One operator performed six measurements on a 24-year-old man, while six operators repeated the process on a 22-year-old woman. The coefficient of variation for these distances ranged from 0.23% to 2.90%, confirming the device's accuracy in linear measurements and craniofacial morphology analysis. Greater measurement distances corresponded with improved accuracy, with coefficients of variation between 0.34% and 1.53%. This limitation may be related to the difficulty in capturing the same facial expression throughout the assessment procedure (9). In this present study, we observe this relationship since the measures Acd-Ace and Cphe-Cphd presented moderate correlation. Demographic points were difficult to measure accurately with a caliper for short distances, but the Vector H2's software magnification tool allowed precise mark identification.

Stereophotogrammetry is currently the most promising method in soft tissue assessment (4). This equipment has gained widespread use across various clinical applications, including anthropometric analysis, surgical planning, facial symmetry evaluation, and facial recognition (3). The ongoing shift toward 3D facial imaging systems has fostered the evolution of various imaging techniques and equipment over time (13). Despite the visible advantages of stereophotogrammetry, the accuracy and reliability of 3D imaging systems need to be established (8). A study evaluated the stereophotogrammetry device by photographing 26 volunteers with both Vectra H1® and 3dMDface® (10). Using each device's software, 136 facial measurements and heat maps were compared. Most surface differences were within ±1 mm, validating the device. Agreement tests classify values from excellent to poor. In this present study, results fell into categories with the agreement between methods. Camison *et al.* (10) reported mainly excellent or very good values, except near the facial midline. Similarly, in this present study, the lowest agreements were found in Acd-Ace and Cphe-Cphd.

Few studies have validated Vectra H2® equipment for children of different ages, making our findings harder to interpret. Further research is needed. This study's validation expands the use of facial analysis tools for children and

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supports research into craniofacial development and the influence of biological and environmental factors.

Conclusions

This study concluded that the evaluated methods demonstrated agreement in facial anthropometry and the Vectra H2® stereophotogrammetry system was confirmed as an applicable method for facial anthropometric analysis in children.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-2025-243/rc

Data Sharing Statement: Available at https://qims.amegroups.com/article/view/10.21037/qims-2025-243/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-2025-243/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was approved by the Institutional Review Board of Bauru School of Dentistry, University of São Paulo (Certificate of Presentation for Ethical Assessment: 64546422.4.0000.5417), as well as full agreement with the Declaration of Helsinki and its subsequent amendments. The parents or legal guardians of all participants provided written informed consent, and the participants themselves provided assent prior to participation in the study.

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