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Advancing digital anthropometry in plastic surgery: Comparing smartphone 3D surface imaging to Vectra H2 in breast reconstruction

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Summary *Background:* Digital anthropometry is a useful tool for surgeons and patients in breast reconstruction surgery (BRS). Owing to advancements in smartphone technology, these devices can be used for three-dimensional (3D) surface imaging. In this prospective study, anthropometric measurements of the breast were performed using a smartphone and compared with measurements obtained using an established 3D surface imaging system.
Methods: In this study, 40 patients who underwent BRS were included. 3D-surface models (SMs) were obtained using the Vectra H2 stereophotogrammetry camera (Canfield Scientific, USA) and an iPhone 15 (Apple Inc., USA) in combination with the 3D Scanner App (Laan Consulting Corp., USA). Fourteen measurements were performed on all 3D SMs. Subsequently, smartphone-based

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measurements were compared to Vectra-based measurements. Statistical methods used were the paired t-test, paired Wilcoxon-signed ranks test, Bland-Altman analyses, and calculation of the intraclass correlation coefficient (ICC).
Results: All measurements demonstrated excellent agreement between those obtained using the smartphone and Vectra H2 (ICC between.963 and.998). No statistical differences were found for 11 of the 14 anthropometric measurements. The Bland-Altman analyses yielded promising results, demonstrating 95% limits of agreement within a range of less than ± 2 mm between the 2 methods.
Conclusion: The proposed method for smartphone-based anthropometry of the breast showed moderate accuracy for clinical use. However, the approach used to create and evaluate the 3D SMs is considered laborious. Therefore, further refinement of the method may be necessary to enable the implementation of smartphone-based surface imaging in plastic surgery.
Clinical trial registration number: DRKS00034221.

Breast cancer accounts for approximately 30.5% of all primarily diagnosed neoplasms in women, with 70.550 new cases reported in Germany in 2020.[1] Despite a slight decrease in mortality rates in the recent decades, the incidence of new cases has increased.[2] With the increasing number of breast cancer survivors, the importance of mastectomy and subsequent breast reconstruction has grown.[3]

As achieving symmetry of the breast is considered a primary goal for surgeons and patients, surgeons require a reliable tool to assess symmetry after breast reconstruction surgery (BRS).[4,5]

Several studies have demonstrated that 3D surface imaging is a valuable tool for assessing breast symmetry, for preoperative planning of BRS and as a post-surgical evaluation tool for aesthetic outcomes.[6-9] In addition, employing digital 3D surface models (SMs) offers precise and reproducible documentation of patient conditions and treatment.[10] Recently, smartphone-based methods for 3D surface imaging have emerged.[11] These technological advancements in smartphone-based 3D surface imaging raise the question of whether smartphone-assisted 3D surface imaging methods are on par with the established methods for 3D surface imaging of the breast, such as stereophotogrammetry. Currently, there is a paucity of studies examining the clinical applicability of this method in plastic surgery.

Han et al. compared manual breast measurements with digital measurements on surface models obtained from the iPhone 12 Pro (Apple Inc., USA) and its built-in LiDAR sensors, using the Innoscan (Innoyard, Ltd., Korea) software application, performing 9 different measurements on 46 participants.[12] Although the authors did not find significant discrepancies in most breast measurements, they noted significant differences in the nipple-to-inframammary fold (IMF) distance due to challenges in accurately capturing this area, particularly in patients with breast ptosis.

Despite promising advancements reported by previous investigation, the generalizability of these findings remains limited due to small sample sizes, a lack of diverse patient populations, and incomplete validation of the technology in various clinical settings.[13] Therefore, this study aimed to assess the utility and accuracy of smartphone-based digital anthropometry of the breast in comparison with the current gold standard for mobile 3D surface imaging, the Vectra H2. This approach has the potential to make a valuable contribution to enhancing efficiency and maintaining accuracy in patient care.

Material and methods

Study protocol

This trial was designed as a monocentric prospective study. It was conducted at the Department of Plastic Surgery at the Hospital St. Josef Regensburg, Germany. Prior to the commencement of the study, a positive approval from the study institution's local ethics committee was obtained under the approval number: 20-1653-101. A total of 40 patients who underwent BRS between October 2018 and October 2023 were included in our study, *as similar sample sizes have been analyzed in several previous studies.*[12,14] Patients who underwent BRS were chosen based on the necessity for reliable symmetry measurement, as symmetry is considered one of the primary evaluation criteria for successful outcomes in BRS.[4] Exclusion criteria involved patients with flap loss, plaster allergy, or unwillingness to participate in the study. *This study was conducted in accordance with the STROBE guidelines.*

3D Data Acquisition

To obtain surface information, the Vectra H2 System (Canfield Scientific, USA) was used in conjunction with the VECTRA Analysis Module (VAM) software. For smartphone-based data acquisition, the iPhone 15 Pro (Apple Inc., USA) was used with the 3D Scanner App (Laan Consulting Corp., USA).

To acquire the scans, patients were instructed to position their arms at a 45° angle to the ground. To ensure high reliability, patients were provided with a stick to assist in maintaining the position. The scans were subsequently obtained sequentially, starting with the Vectra H2.

The Vectra H2 is a portable camera system that generates 3D surface images using stereophotogrammetry. It guides the user with a dual-light point positioning system to maintain a consistent distance from the patient during image capture. Stereophotogrammetry is a well-established technique by which 2 or more pictures are processed to obtain a 3D model by using stereo triangulation algorithms.[15-17] The accuracy and repeatability of such systems have been sufficiently demonstrated in the past decades.[15,18,19] The Vectra H2 comes with the Software VAM, which allows linear and over-the-surface measurements.

The 3D Scanner App uses the advanced camera features of the iPhone, such as the LiDAR-Scanner, camera, or TrueDepth mode to create 3D models. In this study, the Photo Mode was used to create the 3D models. For this, the camera captures a series of images every 0.8 s from different angles to compute a detailed surface model of the patient.

To process the data, the captured images are exported to a MacBook Pro M1 2021 (Apple Inc., USA) using the accompanying 3D Scanner App software (Laan Labs, USA) designed for MacOS (Apple Inc., USA). To perform the geodesic measurements, the SMs were pre-processed with included cutting, scaling, and remeshing. Smartphone-based and Vectra-based SMs were exported as Wavefront OBJ-files. Consequently, the SMs acquired from both methods were imported to Cloudcompare (Cloudcompare.org) for scaling. After cropping the SMs in a standardized fashion slightly above the elbow, neck, and belly button and adjusting the bounding box centers, they were first aligned manually and subsequently more precisely aligned using Cloudcompare's ICP implementation. Figure 1 shows the alignment process of the two 3D models. The scaled smartphone-based SMs were then exported to Meshlab (ISTI-CNR, Italy), where normals were computed for point sets of the smartphone-based SMs.[20] Thereafter, the Screened Poisson algorithm was applied to import the smartphone-based SMs into VAM and perform anthropometric measurements. Lost texture of the smartphone-based SMs was retrieved by transferring the texture from the initially scaled SMs to the processed SMs. This method was solely used for smartphone-based SMs. The Vectra system is designed in such a way that its generated models are automatically scaled and prepared to perform anthropometric measurements in VAM. Subsequently, smartphone- and Vectra-based SMs were imported into VAM to use the measurement tool to acquire anthropometric measurements.

Landmarks

For accurate and reproducible measurements, patients received several landmarks, each consisting of stickers with a 4 mm radius as described previously.[21,22]

The following landmarks were used unilaterally: (1) sternal notch (SN), (6) xiphoid (Xi).

The following landmarks were used bilaterally, on the left (l) and right (r): (2) upper medial breast pole (MUBP), (3) upper lateral breast pole (LUBP), (4) uoracoid process (CP), (5) lateral breast pole (LaBP), (7) lower breast pole (LBP), (8) nipple (N). The upper breast pole was set directly between MUBP and LUPB. The upper breast pole was marked in VAM using a measuring tool to achieve greater accuracy: (9) upper breast pole (UBP). For patients with missing nipple after breast surgery, the position was determined by the authors based on their professional expertise. Figure 2 compares a scaled smartphone-based SM to the corresponding Vectra-based SM after the digital landmarking process.

Anthropometric measurements

The protocol for the anthropometrical measurements employed in our study has been described earlier.[21,22] The following measurements were performed on both sides (right, left):

(1, 6) SN – N, (2, 7) LBP – N, (3, 8) UBP – N, (4, 9) Xi – N, (5, 10) LaBP – N, (11, 13) breast width (LaBP – N – Xi), (12, 14) IMF-length (LaBP – LBP – Xi)

To ensure consistency and reproducibility, one healthcare professional (N.C.) with experience in the field of 3D SM analysis performed all measurements on a computer using the VAM software. As reference points, the center of the associated stickers was selected so that the software could measure the geodesic distances. The UBP, as described before, was set exactly between the upper medial breast point and upper lateral breast point.

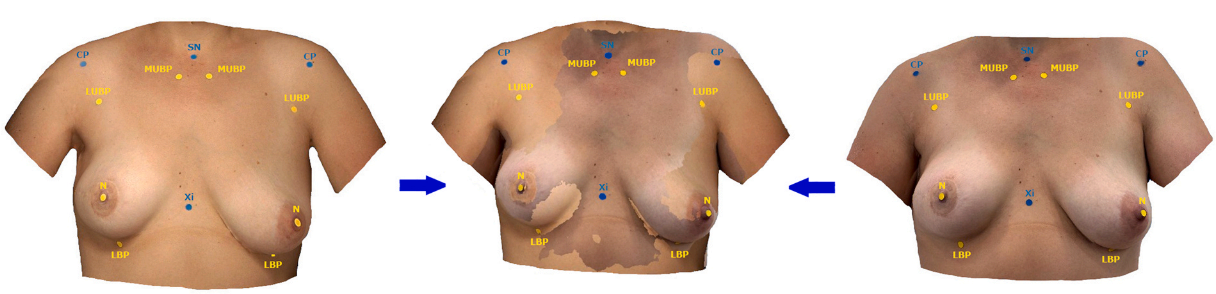

Figure 1 Alignment Process: Appearance of a 37-year-old patient, 60 months after BRS with DIEP flap reconstruction on the right side, following neoadjuvant chemotherapy and axillary lymph node dissection. Surface models (SMs) were generated using the smartphone-based method and Vectra H2. The Vectra-based SM is displayed on the left, while the smartphone-based SM is shown on the right. For comparative analysis, CloudCompare Version 2 was used to superimpose the SMs by using the ICP implementation of the Software. This process ensured accurate alignment and scaling of the SMs following analysis. The landmarks were digitally named to highlight their importance during this process, as they serve as visual checkpoints for successful superimposition.

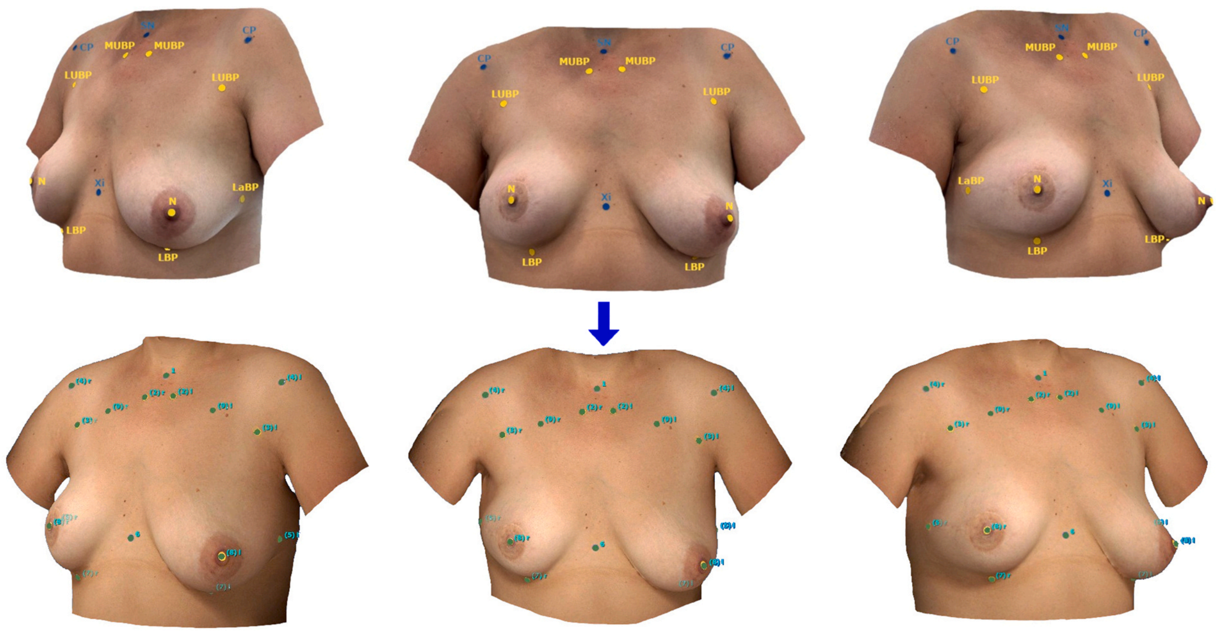

Figure 2 Digital Landmarks: Appearance of a 37-year-old patient, 60 months after BRS with a DIEP flap reconstruction on the right side. On both SMs, the landmarks were digitally labeled using the VAM software to allow for subsequent measurements. The upper images show a smartphone-based SM before the digital marking process, while the lower images display the Vectra-based model after positioning the digital landmarks.

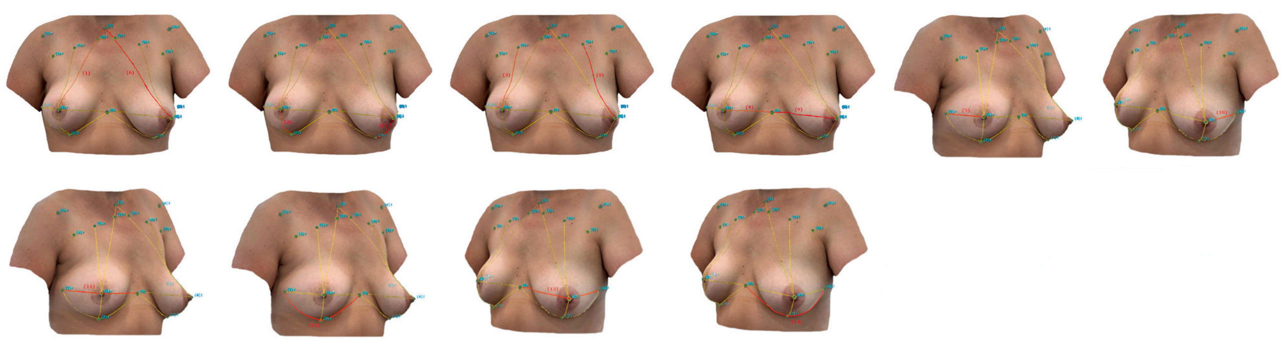

Figure 3 Measurements: Appearance of 37-year-old patient 60 months after BRS with DIEP flap (right). The illustration displays each in VAM performed measurement individually on the smartphone-based 3D SM. Each measurement is highlighted in red. The images of the upper row display measurements between 2 landmarks, while the images of the lower row display the measurements between 3 landmarks.

Figure 3 shows the measurements performed in VAM on a smartphone-based SM.

Statistical analysis

Statistical analysis was performed using IBM SPSS 27 (SPSS Inc., USA). The Kolmogorov-Smirnov test was employed to assess the normality of the data distribution. Consequently, the t-test for paired samples was performed to compare the mean values. The intraclass correlation coefficient (ICC) was used to assess the consistency between measurements. According to previous studies, the reliability is considered poor, when the ICC is less than 0.4, fair when it is between 0.4 and 0.59, good when it is between 0.6 and 0.75, and excellent when it is higher than 0.75.[23] In addition, Bland-Altman analyses were conducted to assess the agreement between both measurement methods. In concordance with previous investigations, 95% Bland-Altman limits of agreement (LoA) of more than ± 2 mm were considered unreliable.[11] Aung et al. categorized the value of measurements on SMs into 4 groups in 1995, where mean differences were considered as highly reliable for mean differences of less than 1 mm, reliable for mean differences between 1 and 1.5 mm, and moderately reliable for mean differences between 1.6 and 2 mm. Mean differences of more than 2 mm were classified as unreliable.[24]

Results

Patient demographics

The cohort consisted of 40 women with a mean age of 51.5 $\pm$ 8 years [range: 32–68 years] and mean body mass index of

Table 1 Descriptive Statistics: Values in cm for Vectra H2-based and smartphone-based measurements (1)-(14).

Variables	Vectra H2				Smartphone			
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD
(1) SN - N R	17.5	37.3	23.5	3.41	17.4	36.9	23.5	3.38
(2) LBP - N R	5.7	13.6	8.3	1.70	5.5	12.8	8.3	1.62
(3) UBP - N R	10.6	29.5	16.6	3.23	10.0	29.3	16.6	3.35
(4) Xi - N R	9.1	17.2	12.2	1.61	9.0	17.4	12.4	1.62
(5) LaBP - N R	7.9	19.4	12.2	2.53	8.0	19.4	12.1	2.53
(6) SN - N L	18.2	29.6	23.8	2.94	18.4	29.6	23.9	2.97
(7) LBP - N L	5.5	12.3	8.1	1.45	5.6	11.9	8.1	1.41
(8) UBP - N L	11.1	23.6	17.0	3.00	11.1	23.6	17.1	3.06
(9) Xi - N L	9.3	16.3	12.9	1.65	9.3	16.3	13.0	1.64
(10) LaBP - N	8.8	16.9	12.4	2.06	8.5	16.2	12.3	2.11
(11) Breast width R	18.0	36.6	24.4	3.52	17.9	36.9	24.5	3.57
(12) IMF-Length R	17.9	38.8	23.9	3.58	18.2	37.5	24.0	3.48
(13) Breast width L	18.0	30.0	25.2	3.21	17.8	30.5	25.3	3.30
(14) IMF-Length L	17.1	31.0	24.6	3.24	16.8	30.9	24.4	3.27

IBM SPSS 27 was used for data analysis.
SD: Standard deviation.

26.3 ± 4.2 kg/m^2 [range: 20.34-39.67 kg/m^2]. Unilateral mastectomy was performed in 37 patients, while bilateral mastectomy was performed in 3 patients. Overall, 18 patients underwent BRS on the left side and 19 on the right side. The mean flap weight on the right side was 622.6 ± 146.4 g [range: 420–857 g], while on the left side equaled 573 ± 395.6 g [range: 178–1550 g]. All patients underwent autologous BRS with deep inferior epigastric perforator (DIEP) flap procedure between 01.10.2018 and 01.10.2023.

Accuracy of measurements between 2 landmarks

Table 1 shows the mean values and range of all measurements between 2 landmarks. The Kolmogorov-Smirnoff test revealed normal distribution for measurements (1) to (5) and (7) to (14). For measurement (6), due to the absence of normality, the Wilcoxon signed-ranks test for paired samples was conducted to compare central tendencies between the 2 methods. All measurements between 2 landmarks (measurements (1) to (10)) demonstrated excellent agreement with ICC values between 0.963 (4) and 0.998 (1 + 6) (Table 2). T-test for paired samples revealed no significant differences in mean values for measurements (1) to (3) and (5) to (10) between Vectra- and smartphone-based measurements: (1) (M = 23.5 vs. 23.5; $p = 0.94$); (2) (M = 8.3 vs. 8.3; $p = 0.64$); (3) (M = 16.6 vs. 16.6; $p = 0.43$); (5) (M = 12.2 vs. 12.1; $p = 0.59$); (6) (M = 23.8 vs. 23.9; $p = 0.44$); (7) (M = 8.1 vs. 8.1; $p = 0.43$); (8) (M = 17.0 vs. 17.1; $p = 0.67$); (9) (M = 12.9 vs. 13.0; $p = 0.27$); (10) (M = 12.4 vs. 12.3; $p = 0.41$) (Table 3). For measurement (4) (i.e., right Xi-N) a significant difference in mean value between Vectra- and smartphone-based measurement (M = 12.2 vs. 12.4) was detected with $p = 0.03$.

The Bland-Altman analyses revealed clinically acceptable agreement between both methods, with 95% Bland-Altman LoA of less than ± 2 mm for measurements (1) to (10). The highest disparity was observed for measurement (4) (−1.94 and +1.32 mm) and was therefore classified as moderately reliable according to Aung et al.[24] The highest agreement and high reliability, with 95% Bland-Altman LoA of less than ± 1 mm between both methods, was observed for measurements between SN - N and LBP - N ((1), (2), (6), (7)), regardless of the side. Furthermore, 95% Bland-Altman LoA of more than ± 1 mm and less than ± 1.5 mm were observed for measurements (3), (5), (8), (9), and (10) and are therefore categorized as reliable.

Accuracy of measurements between 3 landmarks

The values for measurements between 3 landmarks (11) to (14) showed excellent agreement with the ICC values, ranging between 0.996 and 0.998. Table 2 presents ICC values and Bland-Altman LoA. T-test for paired samples revealed no significant differences in mean values for measurement (12) and (13) between Vectra- and smartphone-based measurements (12) (M = 23.9 vs. 24.0; $p = 0.25$); (13) (M = 25.2 vs. 25.3; $p = 0.49$). T-test for paired samples detected statistically significant differences in mean values for Vectra- and smartphone-based measurements for (11) (M = 24.4 vs. 24.5; $p = 0.03$) and (14) (M = 24.6 vs. 24.4; $p < 0.001$) (Table 3) Bland-Altman analysis indicated, that all measurements demonstrated clinically acceptable results, with 95% Bland-Altmann LoA of less than ± 2 mm and even showed highly reliable results with 95% Bland-Altman LoA of less than ± 1 mm.[24] Figure 4 shows a graphical illustration of Bland-Altman analyses.

Overall accuracy

Overall Vectra- and smartphone-based anthropometric measurements showed excellent agreement supported by ICC values consistently above 0.75. Twelve out of 14 measurements demonstrated no statistical differences in central tendencies. According to Aung et al., all measurements showed 95% Bland-Altman LoA that remained within the clinically acceptable range of ± 2 mm.[24] Eight out of the 14 conducted measurements surpassed the expectations with 95% Bland-Altman LoA of less than ± 1 mm and were

Table 2 Intra-class correlation coefficient (ICC) and Bland–Altman Analysis: ICC and Bland–Altman 95% limits of agreement between the two methods.

Variables	ICC	ICC 95% Confidence Interval			Bland-Altman 95% Confidence Interval	
	ICC	Lower	Upper	Mean bias	Lower	Upper
(1) SN - N R	.998	.997	.999	−.03	−.53	.52
(2) LBP - N R	.993	.986	.996	.021	−.54	.58
(3) UBP - N R	.994	.989	.997	−.064	−1.05	.93
(4) Xi - N R	.963	.926	.981	−.314	−1.94	1.32
(5) LaBP - N R	.985	.971	.992	.068	−1.15	1.29
(6) SN - N L	.998	.996	.999	−.05	−.59	.49
(7) LBP - N L	.978	.959	.988	.053	−.77	.88
(8) UBP - N L	.988	.977	.994	−.046	−1.36	1.27
(9) Xi - N L	.971	.945	.985	−.098	−1.18	.98
(10) LaBP - N	.984	.970	.991	.069	−.96	1.10
(11) Breast width R	.997	.993	.998	−.137	−.91	.64
(12) IMF-Length R	.998	.996	.999	−.059	−.69	.57
(13) Breast width L	.996	.992	.998	−.047	−.87	.77
(14) IMF-Length L	.997	.990	.998	.194	−.46	.85

IBM SPSS 27 was used for data analysis.

therefore classified as highly reliable. Five measurements were classified as reliable with 95% Bland–Altman LoA between ± 1 mm and ± 1.5 mm. Only measurement (4) showed moderately reliable results with 95% Bland–Altman LoA between ± 1.6 mm and ± 2 mm.

Discussion

In the present study, anthropometric data of 3D SMs in patients who underwent BRS was obtained by employing 2 different methods: smartphone- and Vectra-based. *Smartphone-based measurements showed promising accuracy compared to the Vectra-based results*. A limitation of the study is that the SMs had to be pre-processed to conduct geodesic measurements. SMs acquired using both the approaches were exported and scaled using Cloudcompare's ICP implementation. To conduct measurements using the VAM, smartphone-based SMs had to be reconstructed using the Screened Poisson algorithm and texture had to be reapplied. This process may have compromised the accuracy of smartphone-based measurements. However, by using this method, the validity increased as both approaches were compared using the same analysis software. Even though the time to capture and generate the 3D SMs is comparable between both the approaches, the preprocessing of the smartphone-based

Table 3 T-test for Paired Samples: Comparison of Vectra H2- and smartphone-based measurements.

Variables	Paired Differences		95% confidence Interval of the Difference		
	Mean	Std. Deviation	Lower	Upper	Two-sided p
(1) SN - N R	−.003	.269	−.089	.083	.94
(2) LBP - N R	.021	.284	−.070	.112	.64
(3) UBP - N R	−.064	.505	−.225	.098	.43
(4) Xi - N R	−.213	.579	−.398	−.027	.03
(5) LaBP - N R	.068	.623	−.131	.267	.49
(6) SN - N L	−.050	.274	−.138	.037	.44*
(7) LBP - N L	.053	.421	−.081	.188	.43
(8) UBP - N L	−.046	.671	−.260	.168	.67
(9) Xi - N L	−.098	.551	−.274	.078	.27
(10) LaBP - N	.070	.526	−.099	.238	.41
(11) Breast width R	−.137	.394	−.263	−.011	.03
(12) IMF-Length R	−.059	.324	−.163	.044	.25
(13) Breast width L	−.046	.418	−.180	.087	.49
(14) IMF-Length L	.194	.334	.087	.301	< .001

IBM SPSS 27 was used for data analysis.
* For measurement (6) Wilcoxon signed-rank test was performed.

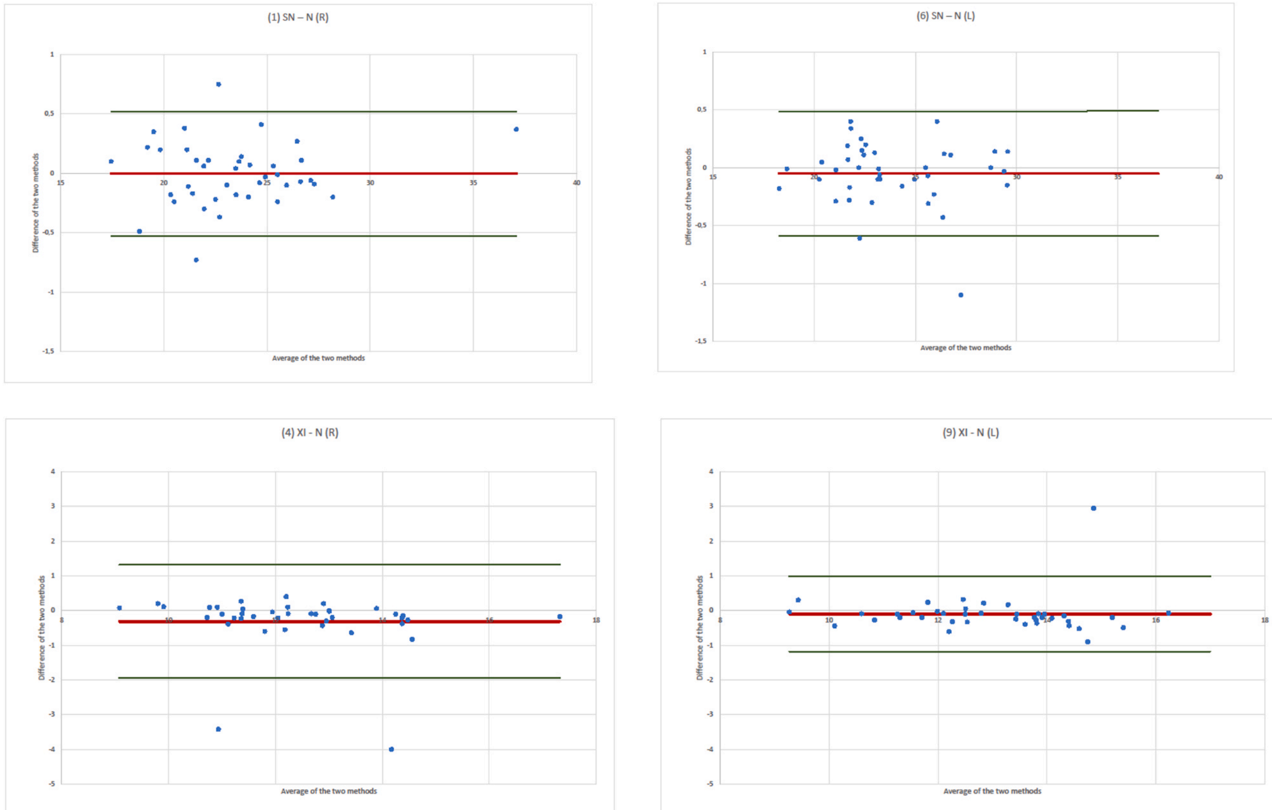

Figure 4 *Graphical Illustration of the Bland-Altman Analyses*: The table displays the graphical representation of the Bland-Altman analysis of the corresponding measurements (1), (6) and (4), (9). The Bland-Altman plots visualize the agreement between the two measuring methods. The x-axis represents the mean of the measurement performed on both SMs in cm. The y-axis represents the difference between the two paired measurements in mm. Each point represents the value of a paired measurement for 1 of the 40 patients. The red line in the center indicates the mean bias between all paired measurements. The two bordering green lines display the limits of agreement, illustrating the range within which 95% of the differences are expected to fall. The Bland-Altman plots show a mean bias close to zero, indicating no systematic difference between the two methods. Most data points fall within the limits of agreement, indicating good overall agreement. However, measurement (4) displays the largest outliers, which are likely due to individual measurement errors. Microsoft Excel 16 was used for data analysis.

scans is considered time-consuming. On an average, this process takes 30 min, underlining the necessity of suitable software to ensure a comparable work effort. The Vectra system's precision has been extensively validated in numerous studies, thereby establishing it as the gold standard.[6,7,14,15,19,25] As the study is limited to comparing 2 different systems and accuracy of the Vectra system is well-documented, any potential for error propagation in the Vectra-based models can be considered negligible. The absence of normality found in measurement (6), may be attributed to the significant variations in flap weight on the left side, resulting in extreme outliers, thus violating the assumption of normality. Furthermore, the deviation in normality for measurement (6), may be explained by ptosis, particularly affecting vertical measurements. The fact that measurement (7) was not affected, highlights a general limitation of stereophotogrammetry, as the method generates SMs and cannot account for the overlay effect caused by ptosis.[8,26] Although the accuracy of the smartphone-based measurements was at least moderately reliable, with less than ± 2 mm discrepancy in mean differences, the workflow has yet to be improved.[24] In comparison to the iPhone, the Vectra H2 comes with an end-to-end solution with functions, such as VAM, to create an easy and comprehensible way to work with, interpret, and export the previously generated 3D SMs. Therefore, if software were developed that combines data generation, processing, and analysis, this major drawback may be overcome. In addition, a potential limitation may be that patients were initially scanned using the Vectra H2, followed by subsequent surface imaging with the smartphone. Despite efforts to minimize patient movement and short scan durations, there were occasional changes in shoulder position. Similarly, De Stefani et al. described that facial movements during scans can affect the accuracy of the generated models.[19] Consequently, movements between 2 different scans may also affect the accuracy of the scan, especially when the SMs are superimposed for scaling purposes. Although shoulder position was not directly accounted for in the measurements, this possibly led to slight deviations within the scaling process. In measurement (4), movements *between the scans* may have contributed to the discrepancy in mean value by causing shifts in breast position, potentially leading to slight breast deformations. A similar effect is plausible for measurement (14), where these movements, combined with ptosis, may have altered the occlusion and further impacted accuracy. Consequently, it is reasonable to conclude, that even more accurate results could be anticipated if the scaling step could be eliminated. Future studies should assess intra- and interobserver reliability to further validate the usage of smartphone-based anthropometry.

As a relatively new technology was investigated, classifying the acquired results was challenging. Rudy et al. compared the accuracy of the Vectra H2 to iPhone X using the ScandyPro application on 10 patients who underwent BRS.[13] The study reported 95% Bland–Altman LoA with a lower limit of −1.9 mm and an upper limit of +2.17 mm for all performed measurements. These findings align closely with those of this study. The use of a more recent iPhone model may account for the observed improvement, as this study demonstrated 95% Bland-Altman LoA consistently below ± 2 mm. Just as in this study, various programs were used in post-processing the smartphone-generated data, which enhances the comparability of the studies and supports our criticism regarding the need for further research and improvement in the suitable software. Although this study examined the accuracy of smartphone-based 3D SMs of the breast, comparing it with similar studies that investigated the accuracy of SMs of the face may provide valuable context to better position our findings. Chong et al. investigated the accuracy of SMs of the face generated using iPhones/iPads (Apple Inc., USA) using a custom-developed application and compared the measurements with direct measurements, that served as the gold standard. Therefore, SMs of 20 healthy volunteers were generated, and 21 different measurements were conducted and compared. The Bland–Altman analyses indicated that 11 of these measurements fell within the 95% LoA, with a deviation of less than ± 2 mm.[27] However, this study has produced impressive results in terms of accuracy, marking a significant step forward in the validation of smartphone-based surface models with highly reliable results in more than 50% of the performed measurements.[24] These findings highlighted the potential of smartphone-based anthropometry, particularly when considering the total cost. Although a comparison between software costs is not feasible owing to the use of the same software, hardware costs differ remarkably with the Vectra H2 exceeding 15,000 USD compared to approximately 1000 USD for the iPhone15 Pro, depending on the country of purchase.[13] Considering the critical importance of patient privacy in clinical settings, particularly regarding images of sensitive body parts, the future implementation of smartphones including corresponding software must comply with data protection guidelines to ensure data security and maintain the trust between patients and clinicians. Therefore, with appropriate improvements in software development and assurances regarding data security, the integration of smartphones into clinical practice could become a viable option. Given the benefits in terms of cost and availability, the method has the potential to evolve as a valuable tool for a broader range of plastic surgeons worldwide, particularly for symmetry assessment following BRS and for documentation purposes.

Conclusion

The proposed data suggest that smartphone-based anthropometry of the breast showed reliable accuracy, with 95% Bland–Altman LoA of less than ± 2 mm. However, the clinical implementation of smartphone-based anthropometry may be compromised due to a complex workflow. The technique of smartphone-based 3D surface imaging demonstrates promising results and has the potential to enhance the daily clinical experience for patients and plastic surgeons.

Ethical approval

The study was approved by the Institutional Ethics Committee of the Medical Faculty at the University of Regensburg, Germany (approval number: 20-1653-101). All procedures conducted in this study adhered to the ethical guidelines of the institutional and/or national research committees, in compliance with the 1964 Helsinki Declaration and its subsequent amendments, or with comparable ethical standards.

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CRediT authorship contribution statement

NC: Data collection, data analysis and interpretation, manuscript writing. MA: Critical revision of the article, data analysis and interpretation. KF: Critical revision of the article, data analysis and interpretation. WS: Critical revision of the article, data analysis and interpretation. AA: Critical revision of the article, data analysis and interpretation. JT: Critical revision of the article, data analysis and interpretation. TE: Critical revision of the article, data analysis and interpretation. LP: Critical revision of the article, data analysis and interpretation. VB: Project development, data collection, data analysis and interpretation, critical revision of the article, final approval. RH: Project development, data collection, data analysis and interpretation, critical revision of the article, final approval.

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Disclosure

The authors state no conflicts of interest related to this study.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.bjps.2025.03.039.

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