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# Three-dimensional Assessment of the Breast: Validation of a Novel, Simple and Inexpensive Scanning Process

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**Abstract.** *Background/Aim: Methods to assess three-dimensionally the breast surface are increasingly used in plastic and reconstructive surgery. The aim of this study was to validate the use of the Structure Sensor 3D scanner (Occipital, Inc., Boulder, CO, USA) connected to an iPad Pro (Apple, Inc., Cupertino, CA, USA) as a novel, inexpensive and handheld three-dimensional scanning process. Materials and Methods: Surface images of a medical human female anatomy torso model of rigid plastic were repeatedly acquired with Structure Sensor 3D scanner and compared with those obtained using two clinically established 3D imaging systems. Digital measurements of vector and surface breast distances were analyzed using Mimics® Innovation Suite 20 medical imaging software (Materialise, Leuven, Belgium). Results: The analysis of variance (ANOVA) revealed no statistically significant difference among measurements obtained using different scanning processes for all the variables examined ( $p>0.05$ ). Conclusion: The study demonstrates analogous*

*practicability and reliability for surface image acquisition using the newly introduced Structure Sensor 3D scanner and other clinically established scanners.*

Three-dimensional photographic imaging technologies are gaining an increasing role in plastic and reconstructive surgery. They allow accurate and efficient pre-operative analysis to formulate diagnosis and establish endpoint goals of treatment to address the underlying morphology and, thus, prepare an appropriate surgical plan (1).

Furthermore, in contrast to traditional two-dimensional photography, three-dimensional imaging is growingly regarded as a fundamental tool to objectively measure outcomes by providing true surface anatomy (2). Notably, volumetric and geometric parameters analyses such as depth and surface topographic distance measurements can also be performed, yielding important additional data (2).

These elements are considered particularly relevant in case of breast surgery, where they can be used to evaluate symmetry, surface and volumetric changes, including total breast volumes, volumetric distribution, and breast projection. Moreover, surface and vector measurements can be assessed to define breast contour, size, and position on the chest wall (3).

A number of researches have indeed validated the use of three-dimensional imaging in the clinical context of autologous or prosthetic breast reconstruction, and breast augmentation and reduction (3-10). Several validated devices are available for three-dimensional breast images capturing. However, many of them are not portable, heavyweight and generally expensive (11). These characteristics make them of unpractical use in the daily practice.

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**Key Words:** 3D scanning, three-dimensional, surface imaging, photogrammetry, virtual surgical planning.

We previously described the use of a novel, simple and inexpensive three-dimensional scanning system for breast surface evaluation (12). The aim of this study was to validate its use in comparison to other clinically established three-dimensional imaging systems.

## Materials and Methods

We performed a scanning process using the Structure Sensor 3D scanner (Occipital, Inc., Boulder, CO, USA) connected to an iPad Pro (Apple, Inc., Cupertino, CA, USA), available at a price of 379 USD. The device is a structured/infrared light handheld scanner that measures 11.92 (width)  $\times$  2.9 (height)  $\times$  2.8 (depth) cm and has a weight of 95 g.

The established Vectra M5 Scanner (Canfield Scientific Inc., Parsippany, NJ, USA) 3D imaging system and Artec Eva 3D scanner (Artec3D, Luxembourg, Luxembourg) were used as a reference. The former is a stationary passive stereophotogrammetry-based system, while the latter is a handled structured light three-dimensional scanning system that measures 26.1 (width)  $\times$  15.8 (height)  $\times$  6.3 (depth) cm and has a weight of 850 g. The last two devices are marketed at a higher price of over 10,000 USD.

The three-dimensional scans were acquired, with all systems, on a medical human female anatomy torso model of rigid plastic in a room with normal illumination. The torso was scanned five times with each device. All scans were imported into the Mimics® Innovation Suite 20 medical imaging software (Materialise, Leuven, Belgium) to obtain from the three-dimensional images the following clinical measurements of each breast: sternal notch-to-nipple distance (S-N); nipple-to-inframammary fold distance (N-I); lateral inframammary fold-to-medial inframammary fold distance (L-M); upper pole-to-inframammary fold distance (U-I). All these distances were calculated both as a surface measurement and as a direct vector measurement. The vector distance between the two nipples (N-N) was also measured.

Furthermore, a single computer tomographic (CT) scan of the torso was also acquired and analyzed through the Mimics® Innovation Suite 20 medical imaging software (Materialise, Leuven, Belgium) as objective reference of the actual values of the measurements.

The analysis of variance (ANOVA) test was performed to determine if the differences among measurements obtained using different scanning processes were significant. Statistical significance was defined as  $p < 0.05$ . All statistical analyses were performed using the SPSS® Advanced Statistical TM software package (ver. 13; SPSS Inc., Chicago, IL, USA).

## Results

We calculated the landmark-based vector and surface distances. No statistically significant difference ( $p > 0.05$ ) was found with regard to all mean distances measured on the three-dimensional images captured using Structure Sensor 3D scanner, Vectra M5 scanner or Artec Eva 3D scanner. Moreover, no statistically significant difference was found in comparison to the images obtained using the CT scanner ( $p > 0.05$ ), with the only exception of the N-I surface distance of the left breast.

In detail, the following results were observed with regard to vector distances: mean L-M distance was equal in the right and

left breast for each scanner with the exception of the CT scan, and ranged between 129.56 mm (SD=0.40) measured with Vectra M5 scanner and 130.07 mm (SD=1.34) measured with Artec Eva 3D scanner, with no statistical difference ( $p=0.77$  in the right breast and  $p=0.75$  in the left breast); mean S-N distance ranged between 179.07 mm (SD=1.06) and 179.77 mm (SD=0.78) in the right breast ( $p=0.43$ ) and between 175.97 mm (SD=0.85) and 176.41 mm (SD=1.22) in the left breast ( $p=0.67$ ); mean N-I distance ranged between 69.18 mm (SD=0.51) and 69.79 mm (SD=0.41) in the right breast ( $p=0.35$ ) and between 69.45 mm (SD=0.38) and 70.03 mm (SD=0.83) in the left breast ( $p=0.42$ ); mean U-I distance ranged between 167.64 mm (SD=0.68) and 168.11 mm (SD=0.24) in the right breast ( $p=0.34$ ) and between 166.07 mm (SD=0.12) in the left breast ( $p=0.20$ ). Finally, the mean N-N vector distance ranged between 195.94 mm (SD=0.44) and 196.57 mm (SD=1.88), with no statistically significant difference ( $p=0.72$ ).

The detailed results regarding surface distances analysis are the following: mean L-M distance ranged between 187.81 mm (SD=1.25) and 189.30 mm (SD=0.99) in the right breast ( $p=0.1$ ) and between 185.44 mm (SD=0.49) and 185.58 (SD=0.61) in the left breast ( $p=0.8$ ); mean S-N distance ranged between 179.99 mm (SD=0.45) and 180.80 mm (SD=0.77) in the right breast ( $p=0.1$ ) and between 178.96 mm (SD=0.81) and 179.26 mm (SD=0.99) in the left breast ( $p=0.09$ ); mean U-I distance ranged between 196.87 mm (SD=0.35) and 197.15 mm (SD=0.30) in the right breast ( $p=0.45$ ) and between 195.40 mm (SD=0.32) in the left breast ( $p=0.70$ ). Finally, the mean surface N-I distance ranged between 69.43 mm (SD=0.31) and 69.73 mm (SD=0.44) in the right breast ( $p=0.40$ ) and between 69.39 mm (SD=0.29) and 69.64 mm (SD=0.19) in the left breast ( $p=0.39$ ), with no statistically significant difference among the Structure Sensor 3D scanner, Vectra M5 scanner or Artec Eva 3D scanner. However, in this last group, a statistically significant difference was observed with the CT scan images ( $p=0.0004$ ).

## Discussion

The application of three-dimensional imaging to breast surgery is a fast-developing concept that has been validated to date by a number of studies for both accuracy and reproducibility of the technology (1-9, 13-18). This has been considered particularly useful for the pre-operative planning and post-operative assessment of operations such as breast reconstruction, breast augmentation and breast reduction, as well as for the assessment of fat grafting outcomes where also small volume variations must be considered (3, 19-21). Our aim was to validate the use of an innovative and inexpensive scanning process.

In their comprehensive overview of the topic, Tepper *et al.* introduced the concept of mammometrics, defined as the establishment of fixed planes and points on three-dimensional

images to perform objective breast measurements (3). We calculated vectors and surface distances among landmarks of the breast and bony anatomical landmarks of the torso that represent important clinical measurements. The difference among the distances obtained using Structure Sensor and the established Vectra M5 scanner and Artec Eva 3D scanner, that was not found to be statistically significant, allowed us to validate the new scanning process.

The reasons for comparing Structure Sensor with Vectra M5 scanner and Artec Eva 3D scanner are based on the already validated use of these devices. In particular, Vectra technology has been used to capture face, neck, breast and body (13) while the clinical use of Artec Eva 3D has been described for the surface assessment of face, torso, upper and lower extremity (22-29). All three scanning processes showed consistent results also in comparison with the CT scanning, with only one exception, further demonstrating their accuracy.

A previous research compared the use of Structure Sensor and VECTRA®XT (Canfield Scientific, NJ, USA) 3D camera system, reaching the similar conclusion that Structure Sensor offers sufficient three-dimensional imaging quality to measure breast distances and volumes (11). In comparison with this research, which was performed in female breast patients, we decided to perform our measurements by using a medical human female anatomy torso model of rigid plastic in order to reduce the possible biases related to the need of ensuring the correct positioning of the patients or artifacts from highly moveable areas. Moreover, our results were also confronted with those obtained with Artec Eva 3D and CT scanners, ensuring a high level of objectivity.

The advantages of the use of Structure Sensor are certainly the portability, easy handleability and the low cost. However, both Vectra M5 and Artec Eva 3D solutions offer advanced software applications which are able to support the analysis of the three-dimensional images. For this purpose, the alternative use of an open access software such as MeshLab 2016 is possible but more complex and requires higher levels of training.

Overall, these findings are particularly important for their applications in the continuously evolving research in the field of breast and body contouring surgeries for both reconstructive and aesthetic purposes (30-36).

In conclusion, this research was able to validate the use of Structure Sensor 3D scanner (Occipital, Inc., Boulder, CO, USA) for breast surface assessment. However, further research in this area is needed to develop standardized procedures that can be used in the daily plastic and reconstructive surgery practice.

## Conflicts of Interest

There are no conflicts of interest regarding this study.

## Authors' Contributions

Study design: Carlo M. Oranges, Florian M. Thieringer, Philipp Brantner, Daniel F. Kalbermatten, Dirk J. Schaefer; Data acquisition and collection: Carlo M. Oranges, Florian M. Thieringer, Benito Benitez, Bilal Msalleh; Statistical analysis: Carlo M. Oranges, Srinivas Madduri, Salvatore Giordano; Manuscript drafting: Carlo M. Oranges. Critical revision: all Authors. Final approval: all Authors.

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