Assessment of Rhinoplasty Techniques by Overlay of Before-and-After 3D Images

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KEYWORDS

• 3D imaging • Stereophotogrammetry • Rhinoplasty
• Postoperative results • Objective measurements

Assessment of facial plastic surgery outcomes is predominantly qualitative in the current literature. Results are analyzed by quantifying physician opinion, as well as patient quality of life and satisfaction. Although the surveys used are standardized and validated, the results are still highly subjective.

Emphasis has therefore shifted to a more objective evaluation of outcomes. Facial measurements provide a quantitative assessment of operative results. Originally, these were performed with craniofacial anthropometry, the direct measurement of the patient in the clinical setting using calipers and measuring tape. Because of the time commitment this caused for the patient, direct measurements were replaced by the measurement of photographs, which are quickly obtained and can be archived for analysis without causing any inconvenience to the patient.

TWO-DIMENSIONAL IMAGING ASSESSMENT OF RHINOPLASTY TECHNIQUES IN LITERATURE

Frontal, lateral, oblique, and base views of the nose are among the standardized images that allow comparison of surgical techniques and results from different surgeons. In the rhinoplasty literature, two-dimensional (2D) photographs have been used to show the effect of cephalic trim, columellar strut, lateral crural steal, and lateral crural overlay on tip rotation and projection.[1,2] Relative measurements of frontal pictures have also been used to show the change in nasal width after spreader grafts.[3]

SHORTCOMINGS OF 2D IMAGING OF THE NOSE

When dealing with 2D digital photographs, there are certain limitations. The face and nose are three-dimensional (3D) structures, and subtleties can be lost when they are portrayed in 2 dimensions. Particularly in the frontal view, it can be difficult to appreciate small irregularities of the nose. Patient positioning is important because slight changes in the Frankfort plane can cause apparent changes in tip rotation and nasal length on the frontal view. In addition, the lens used by the photographer should be chosen to produce the least distortion while maximizing the depth of field to ensure that the whole face is in focus (typically met by lenses between 90 and 105 mm). Lenses with shorter focal lengths provide a better depth of field (so the whole face is in focus) but cause obvious facial distortion.[4] Another pitfall of 2D photography is the lighting. When the angle between the subject-camera axis and the flash is more than 45°, tip-defining points seem wider apart (and vice versa). Measurement errors can also be introduced by magnification, parallax, and differences in subject-to-camera distances.[5]

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Even changing the photographer can cause changes in comparative measurements because of differences in technique and interpretation of the parameters of standardized photography.

3D IMAGING TECHNIQUES

3D imaging has been developed to overcome some of these obstacles and enable more precise evaluation of changes of the nose after rhinoplasty. In addition to angle, distance, and area measurements, 3-D imaging allows calculations of volumes and topographic distances.

Several forms of 3-D imaging modalities have been developed and tested. Computed tomography, 3D ultrasonography, moiré topography, laser scanning, and stereophotogrammetry are just a few of these techniques. Stereophotogrammetry involves taking multiple synchronous photographs from different angles, which are then digitally melded to generate a 3D image. This modality has gained popularity because it does not expose patients to radiation, as in computed tomography.

Our institution uses the 3dMD system (3dMD Inc, Atlanta, GA), which consists of 6 digital cameras, 3 on each side of the patient. A random light pattern is then projected onto the patient's face, and the cameras, which are set in an optimum configuration, capture simultaneous images. The images are captured in 2 milliseconds rather than the 20 seconds necessary for laser scanning, decreasing error from patient movement, and increasing patient convenience.[6] The system is connected to a computer, where the captured dataset is saved. We then use 3dMD Vultus software to upload and manipulate the images. The 6 captured images are merged to produce a single 3D polygon surface mesh, with a resolution of up to 40,000 polygons per 6.45 cm^2. The wire frame is then layered with soft tissue color and features.[7] This results in a 3D image that can be rotated in space and viewed from any angle. The software has an intuitive interface and requires basic computer skills to navigate. The images are dragged and rotated with a point and click of the mouse and the different capabilities of the system are showcased on the toolbar with picture icons. The 3dMD system is one of a few 3D imaging systems currently on the market. **Table 1** shows a list of equipment and software currently available.

VALIDATION AND RELIABILITY

In addition to acquiring data rapidly and noninvasively, stereophotogrammetry has proved to have excellent precision and reproducibility. Lübbers and colleagues[8] (2010) compared 201 direct measurements of a mannequin head with measurements of the 3D images captured by the 3dMD device. Measurements were performed by 3 observers, and repeated 5 times. There were no statistically significant differences between the direct measurements and the measurements of the images. The operator error (error resulting from inaccuracies in placing landmarks) was noted to be 0.1 mm without use of a zoom to magnify the images, and 0.04 mm with a zoom. Weinberg and colleagues[9] (2006) compared 2 photogrammetric systems (Genex and 3dMD) with each other and with direct anthropometry. On a sample of 18 mannequin heads, 12 linear distances were measured twice by each of the 3 methods. Statistically significant differences were observed for 9 of the measurements, but these were consistently on the submillimeter level. It was therefore concluded that the 2 systems produce interchangeable results. Wong and colleagues[10] (2008) measured 18 standard craniofacial distances twice, directly on 20 normal adults. The craniofacial surfaces of the 20 adults were imaged using the 3dMD device and the same distances were measured digitally, twice for each subject. Seventeen of the 18 measurements were found to be within 1 mm of the digital distances. Littlefield and colleagues (2004) tested the imaging system against a high-precision coordinate-measuring device and found the error to be 0.236 mm. Aldridge and colleagues[11] (2005) acquired 2 images of 15 subjects

Table 1
3D Imaging equipment and software (listed alphabetically)

Company	Equipment	Software
3dMD (Atlanta, GA)	3dMDface System	3dMD Vultus
Canfield Scientific Inc. (Fairfield, NJ)	Vectra 3D Imaging System	Mirror Imaging Vectra 3D Sculptor
Genex Technologies	3D Facecam Capture System	3D Surgeon