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Original Article

The Utility of Smartphone 3D Scanning, Open-Sourced Computer-aided Design, and Desktop 3D Printing in the Surgical Planning of Microtia Reconstruction: a Step by Step Guide and Concept Assessment

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ABSTRACT

Introduction: Microtia, a congenital anomaly of the auricle with a wide spectrum of presentation with challenging reconstruction. Management depends on its severity with variable reconstructive options. Preoperative planning is crucial to achieve better results and decrease operative time. In this article, we aim to show the utility of an affordable technology with the use of a smartphone, an open-source computer-aided design (CAD) software, and a desktop 3D printer in planning future ear location for unilateral microtia reconstruction in step-by-step fashion.

Methodology: Facial 3D scanning was done using a smartphone that has a three-dimensional capture system. The scan was then used in an open-sourced CAD software. A mirror image mask was created by reflecting normal side anatomic features to the abnormal side. The mask constitutes the desired area for reconstruction given the ear anthropometrics. Finally, the model was 3D printed

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and fitted to the patient in which incision marking and framework location was planned.

Discussion: Ear reconstruction requires careful assessment and specific technicality in its anthropometric measures. One important aspect in surgical planning resides in future ear location that varies between person to person. This variability makes the reconstructive option more customized based on the patient's needs. The utility of CAD software in the measurement and planning can help predict and optimize postoperative results as possible; however, it has major technical demands and added surgical fees.

Conclusion: Herein, we demonstrate the efficacy of an easy-to-use system beneficial for preoperative planning that is affordable, time-saving, and cost effective.

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Introduction

Ear reconstruction remains a surgical challenge treating patients with congenital ear abnormalities. The challenge lies within the nature of the ear appearance. The ear has a complex three-dimensional (3D) structure with multiple detailed convex and concave structures. In addition, the ear has specific anthropometric measures in which any discrepancy in these measures gives an abnormal appearance.[1]

Microtia is a congenital anomaly of the auricle raging from a smaller than normal ear to a "peanut-shaped" small remnant of skin and cartilage. Anotia is a complete absence of the external ear.[2] The prevalence of microtia was reported to be from 0.83 to 17.4 per 10,000 births.[2] It is most commonly unilateral, affects males more than females, affects the right ear more than the left, and most commonly diagnosed as an isolated finding without an associated syndrome.[2] The management of microtia depends on the severity, whether it is a bilateral or unilateral condition, and the presence of atresia of the external auditory canal. Reconstruction of microtia and atresia include autogenous cartilage techniques, alloplastic implants such as porous polyethylene implants or with a prosthetic external ear.[3,4] One of the most important of the challenges in reconstruction is planning the future ear location to achieve the best esthetic results. Currently, planning is usually done with the assessment of different anthropometric measures of the external ear and face that may utilize a manually drawn template based on the normal side assessment.[3] In this article, we aim to show the utility of an affordable technology using a smartphone, an open-source 3D computer-aided design (CAD) software, and a desktop 3D printer in planning future ear location for unilateral microtia reconstruction in step-by-step fashion.

Materials and methods

The process consisted of three steps that involve 3D scanning of facial features, CAD modeling, and lastly, 3D printing. After obtaining parental consent, the process was explained to the patient. The patient was placed standing with a plain background behind. The scanning was done using an iPhone 12 that has a 3D capture system rotated around the patient's head as described earlier but with the use of an affordable application specific for facial scanning Bellus3D FaceApp (Bellus3D Campbell, CA) with easy-to-use instructions.[5] The patient was 10 years old and was made familiar with the application through trial scans in which the application instructs the patient to move the head in the desired direction. The process after familiarization took 4 min to finalize. After the scanning process was completed, the obtained model was exported as Alias Wavefront Object (.OBJ) format and costs

0.99 US dollars for the export feature with unlimited scanning trials. The file was then loaded into an open-sourced CAD modeling software Blender (Blender Foundation, Vienna, Austria). In Blender, the model was first set in the scene. After that, the sculpt mode was chosen after which mask feature was loaded. In the mask feature, mask extract function was loaded then through manually shading the area of interest over the patient's nasal dorsum, the peri-orbital area extends all the way around the auricle on the normal side. By this, a mask is created over the normal side. The mask was then flipped horizontally on the X-axis using the mirror feature in the object mode. Next, the mask was tested virtually to fit the patient's head, and to delineate the area of interest and future ear location on the microtia side. Finally, the model was made 3D printable using the 3D print addon feature on Blender and then tested for printability on Meshmixer ® (Autodesk Inc.) and finally was exported for printing. Steps were briefly summarized in (Supplementary Video 1). 3D printing was then made using a biodegradable polylactic acid filament on a desktop-fused deposition modeling, Ultimaker 2 + 3D printer. The total printing time was 4 h and 45 min with a cost of 1.34 US dollars per material cost. The model was then fitted to the patient in which the outline of the future ear was estimated based on the auricle rim in the guiding template as seen in (Figure 1).

Discussion

The adoption of 3D printing is rapidly evolving in different medical fields. Personalized medicine resides in selecting the appropriate therapy based on the patient's needs. 3D printing technologies represent a great example in which personalized medicine can be achieved by appropriately planning and creating solutions based on the physical structure of a specific tissue demand.[6] Surgical disciplines have clearly adopted 3D printing with ever-expanding applications starting from visual tactile aids for surgical preplanning up to exclusively customized surgical guides facilitating various interventions specific for each patient.[6] Additionally, preoperative 3D printed models were shown to be superior in their utility as compared to visual 3D images.[7]

Technology, in some aspects, has superior precision details as compared to the regular human analysis.[6] Precision and technicality cannot be over-emphasized when it comes to ear reconstruction. Ear reconstruction requires careful assessment and specific technicality in its anthropometric measures to reach the desired goal. It remains a surgical challenge and a technically demanding procedure. Despite all the efforts done to reconstruct an ear, it remains asymmetrical when compared with the contralateral side.[1] For that, all attempts were made in favor of reaching a maximal symmetrical result.

The options for ear reconstruction usually fall under three main categories that are based on the material used for reconstruction. This is either autologous, alloplastic, or prosthetic ear reconstruction each with their own indications, advantages, and disadvantages.[8,9,10] Furthermore, despite the variety in the techniques, these reconstructive modalities remain a daring task and a struggle to reach a desirable symmetrical shape. Yet, their outcomes and complication rates were highly dependent on surgical experience.[11]

One important aspect in surgical planning resides in ear location and landmarks that vary from person to person relying on many factors that include genetics, age, and ethnicity.[12] This variability makes the reconstructive option more customized based on the patient's needs.[13,14] Preoperative planning is an important factor that reduces operative time and evades any undesirable results.[15,16]

When it comes to ear reconstruction, detailed assessment of future ear placement is of great importance that is based on the topographical relationship of the opposite normal ear in relation to various facial features specifically for unilateral deformities.[17,18] Such assessment takes into consideration the proposed height of the reconstructed ear and is usually compared from the front view to that of the opposite normal ear. Horizontally, a guide of future ear axis is usually parallel to a line drawn over the nasal dorsum axis. The lateral placement is usually estimated based on the distance from the ear to the lateral canthus on the normal side[17,18] These techniques are usually a trial and error in which a proposed visualization of future ear placement is done, and then, a manually drawn reversed picture pattern is made based on such analysis and reflected to the reconstructed side.[17,18] When applying these measures, human error is a confounding variable that slight errors in calculation can occur, which eventually affects the desirable symmetrical outcome. Such error, however, can

Figure 1. Shows the obtained facial mask as a guide fitted to the patient. A. and B. The produced 3D printed facial guide was fitted to the patient maintaining accurate alignment of facial features such as the nose and periorbital area together with the desired rim outlining the normal ear features around the microtic ear**. C.** It shows the desired future ear location and framework size based on the normal ear features, and the planned incision location were marked on the patient.

be minimized with technology-based assessment and measurements aided with 3D-printed guides as discussed previously aiming for a near symmetrical result.

The utility of CAD software in the measurement and planning can help to predict and optimize postoperative results as much as possible; however, it has major drawbacks, which include convenience and added expenses to the surgical fees. With the expansion of technology adoption, nowadays, majority of 3D planning and CAD assessment is facilitated by specialized service providers and companies specialized in this field.[6] Nevertheless, such a way usually needs a cross-talk between the

operating surgeon and the expert engineer, which may sometimes result in delays and increased fees together with the associated logistics that limits the proposed solution.[6]

The use of smartphone in 3D scanning of facial feature represents an interesting tool to acquire such data. Its efficacy was previously investigated and showed a comparable result to higher end systems.[5] Such a system works through the utilization of the 3D capturing system integrated in the smartphone with the utility of different applications that reads and arranges such 3D data. We have utilized an affordable application due to its easy-to-follow instruction particularly that we aimed to scan a pediatric patient. Furthermore, such scans can also be made using a freely available application as described previously[5] but with anticipated challenges in patient positioning and device rotation around the screened subject.

In this report, we showed our proposed solution in a step-by-step fashion to determine the anthropometric and landmarks for unilateral microtia reconstruction using an affordable technology. We showed the utility of using a smartphone to take a 3D scan of the patient's head; then, we used an open-sourced CAD software to analyze the normal ear and to get a mirror image-based guide that was later on 3D printed to plan the proposed future ear placement and incision design. The 3D printed model had precise measurements and landmarks of ear location with different facial features as reference points for the reconstructive procedure. This method showed a legitimate, convenient, cost effective, and easy to learn technique that is comparable to professional service providers but at a very low additional cost.

Conclusion

In this report, we have demonstrated in a step-by-step fashion the utility of an affordable and an easy-to-use technique that is beneficial for unilateral microtia reconstruction planning. With the widespread use of 3D printing and the associated decrease of its expenses, personalized treatment plans can be achieved that paves the way to improve outcome. Additionally, different adoptions can be obtained on the utility of this technique in surgical education and patient counseling that is affordable, time-saving, and cost effective.

Declaration of Competing interests

All authors declare that they have no conflicts of interest to disclose.

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None.

Ethical approval

N/A.

Patient Consent

Consent was obtained.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jpra.2021.06.001.

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