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CASE REPORT
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Preoperative Flap Surgery Simulation for a Case of Cryptotia Using a 3D Printer

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Summary: Cryptotia is a congenital auricular deformity. Common methods of surgical reconstruction involve creating an auricular temporal groove using local flaps and/or a skin graft. However, it can be difficult to determine which method is most suited to the unique 3-dimensional (3D) structure of each cryptotic ear. Here, we showed that creating 3D ear models of a cryptotic ear with a 3D camera and printer and using these models to simulate surgery with two different flap methods (cat's-ear and square) allowed selection of a reconstruction method that led to good outcomes after the actual surgery. The patient was a 7-year-old girl with left cryptotia. A 3D camera was used to acquire 3D data for the ear. After structural analysis, a home 3D printer was used to print the data into 3D ear models using an elastic material. These models exhibited good plasticity. After subjecting the models to simulated cat's-ear and square flap surgeries, the cat's-ear flap method was considered to better reproduce the healthy side of the ear compared with the square flap method for this particular case. Ear morphology during and after the actual surgery closely resembled the model-ear morphology during and after the simulated cat's-ear flap surgery. We successfully created a full-scale 3D model with good plasticity using a 3D camera and 3D printer. This allowed easy, noninvasive preoperative evaluation and identification of the most suitable operation for the specific case, facilitating easier, more successful surgery. *(Plast Reconstr Surg Glob Open 2021;9:e3194; doi: 10.1097/GOX.0000000000003194; Published online 26 January 2021.)*

Cryptotia refers to a deformation of the auricle in which the upper part of the auricle is flexed and buried subcutaneously in the temporal region. Nonsurgical corrective measures can be applied during infancy, while the auricular cartilage is plastic. After this period, surgical treatment may be required.

Many methods of surgical treatment have been reported for cryptotia, including skin grafting and local flaps. Of these, we prefer to use either the cat's-ear flap method[1] or the square flap method.[2] Our recent finite-element analysis showed that the former is particularly suitable when the posterior auricular groove is shallow after the hidden helix is pulled out, whereas the latter is suitable for other cases.[3] However, the complicated 3-dimensional (3D) structure of the auricle in different cases means that the most appropriate surgical method can still be difficult to select.

Here, we describe how we were able to obtain 3D auricular models in a noninvasive manner using a 3D camera and a 3D printer. The models were subjected to simulated surgery using the 2 flap methods, allowing identification of the most suitable method for this specific case. Indeed, the actual surgery with the selected method achieved good results.

CASE

The patient, a 7-year-old girl, had been born with left cryptotia (Fig. 1). Before surgery, we photographed the affected ear with a 3D camera (VECTRA H1; Canfield, Parsippany, N.J.) and used the photographs and dedicated 3D image analysis software to construct a virtual 3D model. This 3D model was converted to stereolithography (STL) data, and loaded into slicer software (Ultimaker Cura, Utrecht, the Netherlands). The model was then sliced into 322 layers, including the foundation (layer height, 0.1 mm;

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Fig. 1. Preoperative image of the patient's ear during 3D camera photography.

Fig. 2. The 3D model after simulated cat's-ear flap surgery. The model could be bent like a human ear. Moreover, the flap could be designed on the model, after which the material could be incised and sutured like human skin during an operation. Another model was subjected to simulated square flap surgery, allowing comparison of esthetic outcomes between the 2 methods for this particular case.

wall thickness, 1.5 mm). The model was then printed using a popular and inexpensive 3D printer (nozzle temperature, 220°C; bed temperature, 40°C; printing speed, 30 mm/s; Creality 3D-10s; Bonsai Lab., Tokyo, Japan) from thermoplastic elastomer filaments (PolyFlex yellow 1.75 mm; Polymaker, Tokyo, Japan). The model was life-sized and accurately represented the ear deformation. The soft material used for the model allowed deformation by hand.

We then 3D-printed 2 identical models. One was subjected to cat's-ear flap incisions with scalpel or scissors, whereas the other underwent square flap incisions. The flaps were then sutured with 5-0 nylon thread, as would occur during the actual surgical procedure. After comparing the 2 models, we considered the cat's-ear flap as the best method for this case (Fig. 2). (**See Video [online],** which displays the 3D models of the cryptotic ear were created using a 3D camera, 3D printer, and elastomer material. This model could be bent, incised, and sutured. Simulated cat's-ear flap and square flap surgeries with the models showed that the cat's-ear flap method yielded the most pleasing functional and esthetic outcomes compared with the healthy side. This predicted outcome was confirmed by the results of the actual surgery with the cat's-ear flap method.)

Surgery was performed under general anesthesia. The cat's-ear flap was designed with the simulation model as a guide. After skin incision, the oblique auricular and transverse auricular muscles were transected. The flap was raised, remodeled, and sutured (**See Video [online],** which displays the 3D models of the cryptotic ear were created using a 3D camera, 3D printer, and elastomer material. This model could be bent, incised, and sutured. Simulated cat's-ear flap and square flap surgeries with the models showed that the cat's-ear flap method yielded the most pleasing functional and esthetic outcomes compared with the healthy side. This predicted outcome was confirmed by the results of the actual surgery with the cat's-ear flap method.). External bolster fixation was applied for a week. At the 6-month follow-up, the auricle retained a satisfactory form and the patient was now able to wear glasses and masks (Fig. 3).

DISCUSSION

Cryptotia and Its Treatment

Cryptotia is attributed to deformation of the auricular cartilage, poor development of the intrinsic muscles of the ear, and/or quantitative deficiencies of the upper ear skin. Noninvasive interventions with splints during the early postnatal period can eliminate the need for surgery or facilitate subsequent interventions.[4] However, approximately 5 months after birth, the plasticity of the

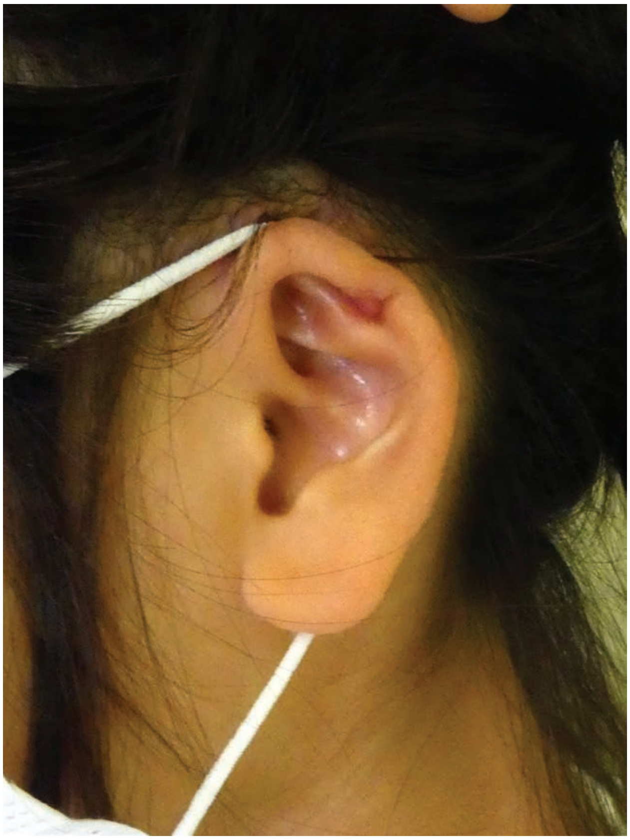

Fig. 3. Six months postoperative image of the patient after surgery. At this time, the patient was able to wear glasses and masks.

ear cartilage decreases and surgery may become necessary. Because patients with cryptotia can have functional disorders, surgery is often performed between the age of 5 and 7 years, once the auricle shows a size closer to that of an adult. The main objective of such surgery is to fill any skin deficiencies and/or modify any cartilage deformation. Moreover, because cartilage deformation is generally due to abnormal muscle adhesion, this adhesion must sometimes be released.[5] Many techniques have been reported, including skin grafts,[5] Z-plasty,[6] transposition flaps,[7] rotation flaps,[8] and V-Y flaps.[9] We prefer to use either the cat's-ear or square flap because these flaps do not require a skin graft, are effective, result in minimal wounds, and do not require the use of unsuitable (hairy) skin. The present study showed that making 3D models of the cryptotic ear from flexible material and then simulating the options for flap surgery helped us choose the optimal method. The cat's-ear flap method was selected, as likely to yield a more natural appearance similar to the healthy side after the flap components were sutured together. This was confirmed by the results of the actual surgery.

Advantages of Simulation with a 3D Camera and 3D Printer

Computed tomography and magnetic resonance imaging are often used to create images for preoperative simulations, but carry the risks of radiation exposure and sedation. These issues are particularly concerning in pediatric cases. Recently, 3D cameras have increasingly been used for 3D structural analyses, follow-up, and simulations in the fields of facial and breast surgery and cases of microtia.[10] However, the use of 3D cameras to analyze cryptotia has not been reported previously. We show here that a 3D camera and a 3D printer helped easily and noninvasively analyze the shape of a child's ear during outpatient treatment. The 3D printer generated an accurate full-scale model of the ear. Moreover, because 3D printer technology is continuously improving, we were also able to create ear models from a soft material with a relatively inexpensive 3D printer. Although the extensibility seen in human skin was lacking, this actually made it easier to see potential skin distortions and dog ears that could arise when a flap method was applied. This in turn aided in selection of the most appropriate method.

CONCLUSIONS

We created 3D ear models in a case of cryptotia, from an elastic material using a 3D camera and 3D printer. By subjecting the models to simulated surgery with 2 flap methods suitable for cryptotia, we were able to select the best surgical method for this case. This approach may thus be useful for selecting between methods of cryptotia reconstruction.

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