# Design and Fabrication of Auricular Prostheses by CAD/CAM System

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***Purpose:*** The purpose of this report is to describe a new technique for fabricating auricular prostheses by a computer-aided design/manufacturing (CAD/CAM) system. ***Materials and Methods:*** A spiral CT was performed on a patient who had a right ear defect resulting from an accident. A 3-D image was reconstructed with the CT data. Through image ware, the image of the normal ear was extracted, mirrored, and Boolean operated with the image of the deformed side of the face. It was well modified and smoothed in the FreeForm model system so that it could precisely adapt to the deficient side of the face. A paper model ear was manufactured by rapid prototyping from the digitized data. Finally, silicone was poured into a silicone mold from the paper ear to create a silicone auricular prosthesis. ***Results:*** The dimension, shape, and anatomic contour of the auricular prosthesis were quite similar to those of the normal ear and precisely matched the deformed area. ***Conclusion:*** The CAD/CAM system for creating auricular prostheses appears to be a practical technique. *Int J Prosthodont 2004;17:460–463.*

Auricular defects may be congenital or acquired and are the second most common craniofacial malformation, after cleft lip and palate.[1–5] There are two main treatments: surgical reconstruction or an auricular prosthesis. The former is a great challenge to surgeons because of the complex shape and size of the human ear. On the other hand, rehabilitation with a prosthetic ear matched to the contralateral ear provides a better morphologic result. However, a successful outcome is completely dependent on the maxillofacial technician's artistry and skill.[6]

Recent advances in technology, including a new generation of compurized tomography (CT) scanners and three-dimensional model-making rapid prototyping (RP) systems, facilitate the production of facial prostheses.[7–10] The purpose of this article is to present a new technique for creating an auricular prosthesis with a computer-aided design/manufacturing (CAD/CAM) system.

## Case Report

A 30-year-old male clinic patient lost his right external ear in a traffic accident and volunteered for the treatment. The deficient side had healed, but some surface scars were present.

The patient's ear was scanned. Contiguous spiral CT scans, of 1.25 mm thickness at 1.25-mm intervals, were generated on a GE Advantage CT scanning system (GE Medical Systems). During the scanning, the patient's head was stabilized, and, after a period of approximately 20 seconds, a zone was scanned from above the supraorbital ridge to below the columella anteriorly,

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**Fig 1** Three-dimensional model of patient's head and ear. Anatomic contours, such as helix, antitragus, earlobe, earhole, and triangle forsa, are clear.

**Fig 2** In FreeForm, different tools are chosen to modify image; holes are completed and margin matches deficient side.

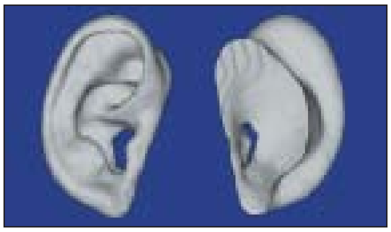

**Fig 3** Digital image of mirrored ear, which is smooth, has no holes, and well matches the margin shape.

and posteriorly from a level above and below the ear; 1.25-mm contiguous axial slices (approximately 70 to 80 slices per ear) were recorded. The data were converted to Digital Imaging and Communications in Medicine (DICOM) and downloaded onto an optical disk.

With a program designed by Shanghai Jiao Tong University, the data could be reconstructed and transferred into an STL file, which is the standard for data interfacing between CAD and RP systems. Magics RP (Materialise) image ware was employed to provide interactive segmentation of the 3-D anatomy, which allowed a visual display of the soft tissues (Fig 1). The image was viewed on a high-resolution monitor. Initially, all of the soft tissue features of the face were displayed, and this image could be rotated so that the surface contour detail of both the unaffected, normal ear and the affected side of the face could be viewed.

The midline of the face was used as the axis of symmetry, and the image of the normal ear was extracted, mirrored, and placed on the side of the face with the deficiency. When there are features (eg, ear hole or earlobe) on the deficient side (as in this patient), the position of the mirrored ear is easy to locate. The software allowed the mirrored image to be moved anteroposterior and superior-inferior and projected from the skull to provide the appropriate prominence of the ear. The ruler and contour lines shown on the screen permitted a check of the symmetry.

The deficient area was somewhat raised because of the scars. Therefore, when mirrored, the image could not exactly match with the deformed side. Some margins would be redundant, and the scarring on the deficient side would protrude into the mirrored ear, affecting the accuracy of the final contour of the ear prosthesis. Therefore, FreeForm (SensAble) was applied. The image of the mirrored ear could be smoothed, and the redundant margin could be sculpted. Materials could be added to cover the scars and would have holes on the image after Boolean operation (Fig 2). During this period, it was important not to damage the shape of the ear. The whole process proved to be easy to learn and quick to complete.

The modified ear image and the deficient side image were chosen to do Boolean operation. Boolean operation, provided by Magics RP, is an operation between two overlapping shapes. It follows the rules of Boolean algebra, which contain union, intersection, and subtraction. In this section, subtraction was chosen. The subtract operation removes the overlapping portion of the second shape from the first shape. In Magics RP, if Boolean is chosen (menu tooling), the two overlapping shapes turn into two colors, red and green. The menu asks the user whether subtracting red from green or green from red is required. If the ear is red and the deformed area is green, green is subtracted from red. The mirrored ear was obtained in this manner and was smooth, without holes, and matched the deficient side exactly (Fig 3).

The data of the final ear image were exported to a Zippy-I RP machine (Kinergy Mechatronics). By a laminated object manufacturing (LOM) system, a paper ear model was made. Silicone was used to make a cavity block of the paper ear by vacuum casting (Fig 4). Then, according to the patient's skin color, pigment was added into the elastomer. Elastomer (Shanghai Silicone Lab) is poured into the silicone cavity to create a silicone auricular prosthesis.

The prosthesis was tried on the patient and found to harmoniously match the deficient side of the face, since the dimension, shape, and anatomic contour of the auricular prosthesis were quite similar to those of the normal ear (Fig 5).

**Fig 4a** *(left)* Paper ear of RP model.

**Fig 4b** *(below)* Cavity block formed by vacuum casting.

**Fig 5** *(left and below)* Silicone auricular prosthesis is harmoniously matched to deficient side of face. Dimension, shape, and anatomic contour are quite similar to those of the normal ear.

## Discussion

To solve the problem of how to match the deficient site of the face perfectly, Coward et al[11] employed RP techniques and the two-time casting method to successfully fabricate a wax ear that matched the remnant tissues. In this case, the FreeForm modeling system was applied to address the above-mentioned problems, and a silastic ear prosthesis was acquired without the extra casts needed to fabricate the wax ear.

Design and fabrication of auricular prostheses by CAD/CAM are advantageous, since a highly skilled technician is not required to sculpt a wax ear. The whole process is undertaken solely on the computer, and the patient can see the result on the screen before the ear is fabricated. It takes about 1.5 hours to finish the fabrication, much faster than the traditional process. In addition, the digital image and silicone mold can be preserved. The latter is durable and permits multiple pourings. This is important, since a replacement is usually required every 2 years because of discoloration of the pigments in silicone elastomer.[12]

Five similar cases were finished using the CAD/CAM system. We have noticed that a lot of ear prostheses are made for patients with micromia, whose faces are asymmetric. The Magics RP program allows the mirrored ear's position to be moved anteroposterior and superior-inferior and projected from the skull to provide the appropriate prominence of the ear. Furthermore, an ear database is created in our lab and each ear model's size can be magnified or decreased horizontally or vertically. However, improvement of the technique is required.

The use of spiral CT and RP is a convenient and effective approach to fabricating an auricular prosthesis that fits the deformed side of the face.

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*Literature Abstract*

**The development of a new index for measurement of incisal/occlusal tooth wear**

The purpose of this article was to develop a new wear index to record incisal and occlusal wear on serial dental study casts. Ten sets of maxillary and mandibular casts were retrieved from archived records that were at least 20 years old (ranging from 20 to 24 years; mean 21.7). The casts were mainly from dental students (age range 19 to 23 years; mean 21.4 years) and the researchers made sure that the subjects were available for a new set of casts to be made. Six assessors were asked to evaluate all the models after being briefed by the researchers and shown photos of the indices. Incisors, canines, premolars, and molars were grouped accordingly and ranked from a scale of 0 to 5 with 0 representing no wear and 5 representing the other extreme from incisal height being reduced by one third crown height to flattened occlusal surfaces. Partially erupted teeth or heavily restored teeth were not included in the scoring. Teeth were also not scored if there was significant cast damage. Validity of the index was measured through intra and inter operator agreement using percentage agreement scores as well as kappa statistic. Interassessor agreement was fair to moderate and intra-assessor agreement was judged to be moderate to good. One assessor was judged to have fair intra-assessor agreement, and this was attributed to limited experience as a dentist. There was no significant wear noted on any of the subjects evaluated over the span of 20 years.

**Hooper SM, Meredith N, Jagger DC.** *J Oral Rehabil* 2004;31:206–212. **Reference:** 20. **Reprints:** Dr D.C. Jagger, Division of Restorative Dentistry, Department of Oral and Dental Science, Bristol Dental School and Hospital, Lower Maudlin Street, Bristol, BS 2LY, UK. e-mail: d.c.jagger@bris.ac.uk—*J. Esquivel-Upshaw, San Antonio, TX*