

Auricular Total Reconstruction with Radial Forearm Prelaminated Flap Assisted by 3D Surface Imaging and 3D Printing

Marco Aurelio Rendón-Medina, MD
 Erik Hanson-Viana, MD
 Leidy Arias-Salazar, MD
 Jorge Arturo Rojas-Ortiz, MD
 Maria de los Angeles Mendoza-Velez, MD
 Rubén Hernandez-Ordoñez, MD
 Hecly Lya Vázquez-Morales, MD
 Ricardo C. Pacheco-López, MD

Summary: The anatomic position of the auricle leaves it vulnerable to traumatic lesions. In most cases, the best reconstructive outcome is accomplished using a temporoparietal flap with a costal cartilage frame and a partial thickness skin graft. Exceptional cases may require different approaches because the reconstructive goals could be more structural than aesthetic. An important factor in this regard is the mechanical properties of the skin that will provide coverage. This study aimed to share a particular case of total auricular reconstruction assisted by 3D surface imaging and 3D printing in a radial forearm free flap. We present a 58-year-old man with a history of having tympanic barotrauma causing hearing loss, burdening him with the use of auricular devices for hearing assistance. Seven days before presenting for the initial treatment, he sustained ear trauma while performing mechanical reparations in a car. The wheel was activated, causing a total amputation of the right ear. He first went to another hospital, where they performed primary closure and then referred him to our unit. The team performed a prelaminated radial forearm free flap assisted by 3D scanning and planning. A detailed comparison between the left ear and the result of the reconstruction was measured and described. The radial forearm prelaminated free flap is a viable structural alternative with the disadvantage of poor auricular definition in some cases. (*Plast Reconstr Surg Glob Open* 2022;10:e4580; doi: 10.1097/GOX.0000000000004580; Published online 13 October 2022.)

The anatomic position of the auricle leaves it vulnerable to traumatic lesions.^{1,2} The most common classification of ear trauma is Weerda classification. Among its degrees, degree I (37%) is the most frequent, followed by degree IV (35%), total amputation due to trauma. Men had a predominance of 4:1 over women. The age group that is most commonly affected is those aged around 30 years, the etiology of this condition is automobile accidents or violence, and the left ear is most affected (55%).²

The initial step is to classify the grade of trauma to reconstruct according to Weerda classification.¹ This

classification divides trauma into 10 grades, where total ear reconstruction is number 7. In most cases, the best reconstructive outcome is accomplished by a temporoparietal flap with a costal cartilage frame and a partial thickness skin graft.^{1,3,4} Exceptional cases may require different approaches because the reconstructive goals could be more structural than aesthetic.⁵⁻¹¹ An important factor in this regard is the mechanical properties of the skin that will provide coverage.¹² It is mandatory to individualize patients' requirements, which could be either structural or aesthetic.

A proportion of patients may want a structural frame to support eye glasses, face masks, or hearing assistance devices. The mechanical properties of coverage are factors to avoid cartilage frame extrusion—a rare complication, but catastrophic.¹² Evidence shows that submandibular and forearm skin is the best for covering stiff implants or cartilage frames.¹²

This study aimed to share a particular case of total auricular reconstruction assisted by 3D surface imaging and 3D printing, in a radial forearm free flap. Zhou et al¹³ presented a three-dimensional cartilage frame design,

From the Department of Plastic and Reconstructive Surgery, The General Hospital "Ruben Leñero," México City, México.

Received for publication April 10, 2022; accepted August 9, 2022.

Ethics approval: All procedures were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. All procedures were approved and performed in regulation with Official Mexican Standard, and International Council for Laboratory Animal Science (ICLAS).

Copyright © 2022 The Authors. Published by Wolters Kluwer Health, Inc. on behalf of The American Society of Plastic Surgeons. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

DOI: 10.1097/GOX.0000000000004580

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. No funding was received for this study.*

Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

and in this case, some of the planning was followed by this specific technique, but with adaptations that diminishes the cost.

Case Presentation

We present the case of a 58-year-old man with a history of tympanic barotrauma, causing hearing loss and resulting in the use of auricular devices for hearing assistance. Seven days before presenting for the initial treatment, he sustained ear trauma while performing mechanical repairs in a car. The wheel was activated, causing a total amputation of the right ear. He went to another hospital, where they performed primary closure and then referred him to our unit (Fig. 1).

The patient had a specific need to continue using his hearing device. The unit initially suggested a temporoparietal flap with a partial thickness skin graft, and then the alternative of a radial forearm free flap, offering an efficient cephalon-auricular angle and good thickness coverage, which could support the device without cartilage exposure. (See Video [online], which displays images of the case, plan, surgical technique, evolution, and final results.)

Using a Kinect¹⁴ probe (version 1, Microsoft Corp., Redmond, Wash.), the team conducted 3D surface imaging of the contralateral, as reported by Basheet et al.¹⁵ Here, the objective was to show the patient how the ear could look. (See Video [online].) Before conducting surgery, the team wanted to show the patient the simulation of what he could expect, and also, the team used these models to create the cartilage frame to see patient-specific auricular anatomy.

Using the simulated ear, the team conducted a harvest of synchondrosis on the right side of the chest (Fig. 1). Then, the team performed a monolithic structure following the Brent cartilage frame technique.¹⁶ Later on, the team found that the patient's cartilage was porous and could easily be destroyed, resembling ashes. So technical manipulation of the cartilage frame was more difficult than expected. (See Video [online].) The frame was introduced in a subcutaneous pocket between a cutaneous flap and the arm volar fascia. Then we waited for 3 months before performing the second procedure. (See Video

[online].) The team implemented the 3D printed models to use as a guide during cartilage crafting and for making frame crafting more comfortable to perform. (See Video [online].) Unfortunately, the team did not measure the frame to present it as valid data. In the future, the team will gather data from more cases to present a comparison of methods.

The team expected reabsorption of the cartilage frame, resulting in a smaller ear, but instead, the team found an unexpected growth of 1cm in every direction. To achieve the best symmetry, the team simulated and measured the degrees of the contralateral ear. (See Video [online].) In the second intervention, the team performed a radial forearm free flap (Fig. 1). Using the radial artery anastomosed to the facial artery and a concomitant vein, to avoid congestion, the team performed the cephalic vein to the external jugular vein anastomosis. The prelaminate flap did not present complications during hospitalization. Following Dimeri et al, the team performed a skin graft with Integra in a single stage for the donor area.¹⁷⁻¹⁹ Hours later, a hematoma appeared, which was treated with drainage and vacuum-assisted therapy. The hematoma resulted in a donor area loss of 98%. Fifteen days later, the team repeated Dimeri's Integra one stage with no complication. The radial forearm flap did not present any complications. Then the patient was discharged with a complete reconstruction. (See Video [online].)

When comparing the reconstructed ear with the healthy one, the following differences were found: in dimensions, a deviation of 3mm on the longest axis, and 2mm on the shortest. In the angles, a deviation of 5 degrees with the root of the helix, 0 degrees in the helix-lobule, and 0 degrees in the cephalon-conchal angle. (See Video [online].)

DISCUSSION

Multiple technological 3D imaging devices with IOS, Android, and web pages are available, which vary in precision and cost. Here, the objective was to describe 3D scanning in general and not to suggest the probe Kinect as the only option for 3D scanning or the only method of 3D imaging.

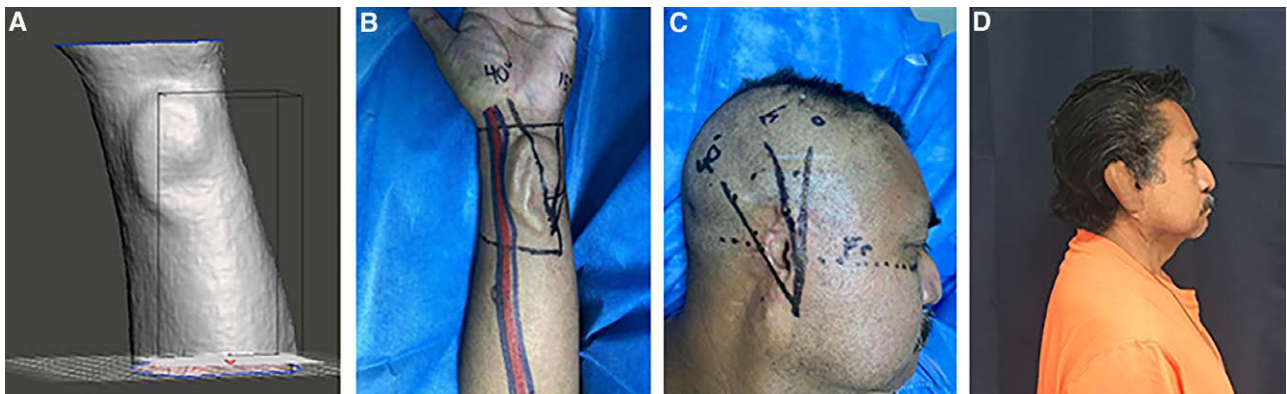


Fig. 1. Simulated ear angles (A), and angles planned in forearm radial flap and pedicle vessels (B). The angles that match the position in the temporal region (C), and finally, the postoperative result (D).

Any sensor could be a candidate for 3D surgical planning, but more rigorous systematized clinical trials are needed to add external validation to 3D imaging with any of these options. So, the team will not compare our single finding with any of the options so as to avoid bias in suggesting one over another. The cost of our planning was low because the team used a second-hand Kinect sensor and the software Skanect (which requires a single pay for the license). The cost of digital planning, software, and hardware planning was \$251. In México, second-hand Kinect sensors are affordable, but in other geographical areas, they may cost more.

In this case, the mechanical properties of the radial forearm skin were fundamental to ensure cartilage frame coverage. This patient can use his hearing-assistance device, glasses, and face mask with ear straps for pandemic protection. The functional perks of this type of reconstruction outweighed the aesthetical outcome of the temporoparietal flap.

The team found that our ear frame grew in every direction, leaving us a bigger ear than the contralateral. However, it is difficult to predict which confounding variables of the patient triggered this effect. For this reason, the team reserved to preach something like that. Undoubtedly, many questions appeared to us after this clinical case, and for this reason, the team is motivated to share our findings.

CONCLUSIONS

The radial forearm prelaminate free flap is a viable structural alternative with the disadvantage of poor auricular definition in some cases. Reimplantation is still the best reconstruction alternative secondary to temporoparietal flap with partial-thickness skin grafts. It is necessary to individualize the needs of every particular case to offer the best auricular reconstruction. Our digital planning helped with patient communication and surgical planning, but randomized blinded studies are necessary to recommend the application of this technology.

Marco Aurelio Rendon-Medina, MD

Hospital General “Dr. Rubén Leñero”
Calle Salvador Díaz Mirón 344, Miguel Hidalgo
11340 Ciudad de México
México
E-mail: dr.rendon1989@gmail.com

PATIENT CONSENT

The patient provided written consent for the use of his image.

REFERENCES

- Weerda H. *Surgery of the Auricle: Tumors, Trauma, Defects, Abnormalities*. Stuttgart, Germany: Thieme Editorial; 2007.
- Gutiérrez-Gómez C, Pradel-Mora JJ, Pérez-Dosal M, et al. Estudio epidemiológico del trauma de pabellón auricular en el Hospital General Dr. Manuel Gea González, México. *Cirugía Plástica Ibero-Latinoamericana*. 2018;44:287–295.
- Villamil V, Bejarano Serrano M, Riba Martínez M, et al. Temporoparietal fascia flap for auricular reconstruction. *Cir Pediatr*. 2021;34:51–55.
- Akin S. Burned ear reconstruction using a prefabricated free radial forearm flap. *J Reconstr Microsurg*. 2001;17:233–236.
- Reitz C, England C, Johnson ON III. Cartilage framework fixation with 2-octyl cyanoacrylate in a prelaminate radial forearm free flap total auricular reconstruction. *Cureus*. 2019;11:e6389.
- Horta R, Valença-Filipe R, Carvalho J, et al. Reconstruction of a near total ear amputation with a neurosensorial radial forearm free flap prelaminate with porous polyethylene implant and delay procedure. *Microsurgery*. 2018;38:203–208.
- Collar RM, Byrne PJ. Images in clinical medicine. Pre-laminated free flap for auricular reconstruction. *N Engl J Med*. 2013;369:1151.
- Rober C, Aki F, Ishida L, et al. Total ear reconstruction with prelaminate radial forearm flap. *J Reconstr Microsurg*. 2006;22:947937.
- Pribaz JA, Pribaz JJ. Prefabricated and pre-laminated flaps for head and neck reconstruction. *Clin Plast Surg*. 2001;28:261–272.
- Flaherty F, Militelli F, Vizcay M. Partial ear reconstruction with a pre-laminated induced expanded radial artery flap. *Plast Reconstr Surg – Glob Open*. 2020:1–3.
- Nehrer-Tairysh GV, Millesi W, Schuhfried O, et al. A comparison of the donor-site morbidity after using the pre-laminated fasciomucosal flap and the fasciocutaneous radial forearm flap for intraoral reconstruction. *Br J Plast Surg*. 2002;55:198–202.
- Griffin MF, Leung BC, Premakumar Y, et al. Comparison of the mechanical properties of different skin sites for auricular and nasal reconstruction. *J Otolaryngol Head Neck Surg*. 2017;46:33.
- Zhou J, Pan B, Yang Q, et al. Three-dimensional autologous cartilage framework fabrication assisted by new additive manufactured ear-shaped templates for microtia reconstruction. *J Plast Reconstr Aesthet Surg*. 2016;69:1436–1444.
- Henseler H, Bonkat SK, Vogt PM, et al. The Kinect Recording System for objective three- and four-dimensional breast assessment with image overlays. *J Plast Reconstr Aesthet Surg*. 2016;69:e27–e34.
- Basheet MH, Al-dahan ZT. High accurate reconstruction of external ear by use low-cost 3D scanner. *Int J Adv Technol Eng Explor*. 2017;4:174–180.
- Behar BJ, Mackay DR. Brent technique for microtia reconstruction. *Oper Tech Otolaryngol – Head Neck Surg*. 2017;28:77–83.
- Jacoby SM, Bachoura A, Chen NC, et al. One-stage Integra coverage for fingertip injuries. *Hand (N Y)*. 2013;8:291–295.
- Burd A, Wong PS. One-stage Integra reconstruction in head and neck defects. *J Plast Reconstr Aesthet Surg*. 2010;63:404–409.
- Demiri E, Papaconstantinou A, Dionysiou D, et al. Reconstruction of skin avulsion injuries of the upper extremity with Integra dermal regeneration template and skin grafts in a single-stage procedure. *Arch Orthop Trauma Surg*. 2013;133:1521–1526.