Thoracic customized modular titanium-printed prosthesis

José L. Aranda, Nuria Novoa, Marcelo F. Jiménez

Thoracic Surgery Department, Salamanca University Hospital, Faculty of Medicine, University of Salamanca, Salamanca, Spain

Correspondence to: José L. Aranda. Thoracic Surgery Department, Salamanca University Hospital, Faculty of Medicine, University of Salamanca, Paseo San Vicente 58-182, 37007 Salamanca, Spain. Email: joluaral@outlook.com.

Abstract: Tridimensional custom-made titanium-printed prosthesis have gained certain relevance as an alternative for chest wall reconstruction although different limitations such as uncomfortable intraoperative placement, long manufacturing time or high costs hinder its use when compared to other standard devices. Trying to overcome these problems, we developed a new model of customized modular titanium-printed prosthesis (CM-TPP) for chest wall reconstruction after breast metastasis resection that seems to offer some advantages over other custom-made reconstructive devices.

Keywords: Customized prosthesis; chest wall reconstruction; chest wall resection; sternal tumor; titanium prosthesis

Received: 22 April 2019; Accepted: 27 June 2019; Published: 24 September 2019.

doi: 10.21037/acr.2019.08.01

View this article at: http://dx.doi.org/10.21037/acr.2019.08.01

Introduction

Since the implantation of our first device in 2015 (1), tridimensional custom-made titanium-printed prosthesis have gained certain relevance as an alternative for chest wall reconstruction (2,3). However, its use is still under heavy debate (4) mainly due to limitations such as uncomfortable intraoperative placement, long manufacturing time or higher costs than other standard devices.

Making a sincere self-criticism, our first prosthesis had some drawbacks: intraoperative placement was uncomfortable due to its lack of flexibility. Furthermore, the implant was rather more expensive than other standard prosthesis and the manufacturing time was too long considering we were facing an aggressive tumor. To overcome these problems, we developed and implanted a new model of customized modular titanium-printed prosthesis (CM-TPP) for chest wall reconstruction after metastatic breast carcinoma resection that seems to offer some advantages over other custom-made reconstructive devices.

Case presentation

A 72-year-old woman with previous surgery for a right breast carcinoma developed a 3.3 cm × 3.2 cm mass involving the sternal manubrium, right sternoclavicular joint, first three ribs and medial border of pectoralis major muscle (*Figure 1A*). No other local or distant metastasis were found on PET-CT. Needle biopsy of the lesion was positive for metastatic breast carcinoma.

Post-resectional reconstruction was planned by means of a CM-TPP. Basically, the design and manufacturing process was similar to that previously described (1) but this new prosthesis had a modular structure with three independent pieces (two lateral "combs" ended in tulip fixations plus a central axis) (*Figure 1B,C*).The final implant was designed using a Solidworks Software (IDONIAL, Gijón, Spain) and printed in an EOS M280 Direct Metal Laser Sintering device (CEIT Biomedical Engineering, Košice, Slovak Republic).

An *en-bloc* resection of right pectoralis major, superior sternal third and internal head of right clavicle along with the first three right ribs plus the second and third left ribs was performed, leaving a small remnant of sternal manubrium attached to left clavicle and first rib. During peritumoral dissection, severe hemorrhage occurred due to lesion of the superior vena cava that required transfusion; after controlling this problem, CM-TPP was placed sequentially (*Figure 2*): first we anchored both combs to its

Figure 1 Surgical planning. (A) CT scan showing involvement of chest wall structures, the white arrow indicates the tumor. (B) Detail of modular structure of the prosthesis. (C) Assembled device.

Figure 2 Surgical implantation of the prosthesis (5). Available online: http://www.asvide.com/watch/32937

respective rib stumps, then attached them with screws to the central axis to end up fixing the manubrial remnant and distal sternum with steel wires sutures (*Figure 3A*). The prosthesis was covered with a pectoralis major flap and the patient was transferred to the recovery room where required prolonged mechanical ventilation due to respiratory insufficiency and psychomotor agitation that prevented weaning. On postoperative day 15, the patient was transferred to the ward were chest physiotherapy was initiated and oxygen therapy was rapidly discontinued. Postoperative pain management was conducted according to the current service protocols (6). No other morbidity was registered. The patient was discharged home 28 days after surgery and prior chest Rx showed a stable reconstruction, with preservation of thoracic morphology and excellent cosmetic results without thoracic pain or dyspnea (*Figure 3B*). Histopathology of the resected specimen confirmed infiltration by ductal breast carcinoma. Although superior sternal third and internal head of right clavicle were removed, the range of joint mobility of the right upper limb one year after surgery was almost normal with only a slight limitation of 10 degrees to shoulder flexion. Mobility of the left shoulder was also normal.

Discussion

Despite the great advances made in the field of 3D printing, the use of custom-made thoracic prostheses has been quite limited for different reasons (4). Given our previous clinical experience, we aimed to develop a new model of CM-TPP that seems to offer some clear advantages over other custom-made reconstructive devices.

Additive manufacturing costs are shared between design, printing itself and processing (separation of the prosthesis from the plate on which is printed, roughing and polishing) (*Figure 3C*). This prosthesis was cheaper than our *en-bloc* prosthesis and the savings occur in all phases of the process: first, some characteristics are used from previous devices (for example, anchoring tulips), simplifying the 3D design; secondly, different plate spatial arrangements are pre-tested to ensure that only the smallest plates with the indispensable guides and the minimum dead spaces between the pieces are used for printing, which in turn greatly simplifies and shortens the processing phase compared to *en-bloc* devices; thirdly, the printing of *en-bloc* prostheses requires "large" and complex 3D printers whose acquisition price and price per hour of work is substantially higher than that of the "smaller" 3D printers where these modular prostheses can be printed. It is very important to bear in mind that the cost of a personalized device can hardly be compared with that of another patient because each of them is different and unique. Given the excellent results and the absence of complications related to the prosthesis itself, we

Figure 3 Manufacturing and surgical placement. (A) Final placement of the prosthesis. (B) Results 1 month after surgery. (C) On-plate printed prosthesis before post processing.

believe that the efficiency of modular prostheses should be similar to those of other standard reconstructive methods (titanium bars, meshes…), although we admit that to confirm this aspect, a cost analysis study should be carried out. Besides this and in comparison with our first device (1) the manufacturing time was reduced from approximately one month to only three weeks, thanks to the use of some characteristics of previous designs, printing optimization and shortening of the subsequent processing phase.

Although the modular design of this device is completely new, we decided to use our "classical" and already tested fixation system (tulip anchorage to the rib stumps) in order to simplify the design process. Regarding the joints between the central axis and the lateral combs, every piece of our new implant was designed within a topological optimization system to achieve a thinner and lighter prosthesis without alteration of its mechanical properties compared to an *en-bloc* device.

After resection of the internal head of the right clavicle and the first rib, the sternoclavicular joint was not fixed to the prosthesis. A polyethylene mesh (visible in *Figure 3A*) was attached to the posterior side of the prosthesis, filling the space below the clavicular stump to protect the subclavian vessels. Given that *en-bloc* prostheses with tulip fixation systems are not flexible enough, once one side of the prosthesis is anchored to the stumps of the ribs, it is necessary to force it laterally to be able to firmly adjust the tulips of the other side in the defect of the chest wall with risk of costal fracture. On the contrary, the modular structure allowed a better and more symmetrical fit of the prosthesis in the stumps of the ribs without the need to force them, to the point that the locking screws of the tulips were almost unnecessary; we can hypothesize that this form of modular prosthesis insertion without need of forcing the stumps of the ribs causes less tissue damage with less postoperative inflammatory response, which in turn leads to a decrease in pain.

Major morbidity consisted in prolonged mechanical ventilation not attributable to prosthesis disfunction. Immediate postoperative results were excellent and no local complications have been detected in one year of follow-up although theoretically the articulation between the bone and the prosthesis could be a source of local complications (rupture of the suture with displacement of the joint, bone erosion…). The impact of joint resection on the range of mobility was low, since the right upper limb showed only a slight limitation of 10 degrees to the flexion of the shoulder. On the left side, mobility of the shoulder was normal.

Conclusions

We believe that CM-TPP are a real alternative to actual *en-bloc* customized prosthesis in terms of better surgical placement, shorter manufacturing time and decreased costs. However, more clinical experience is needed with these types of implants to confirm our initial results.

Acknowledgments

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Written informed consent was obtained from the patient for publication of this case report and any accompanying images.

References

1. Aranda JL, Jiménez MF, Rodríguez M, et al. Tridimensional titanium-printed custom-made prosthesis for sternocostal reconstruction. Eur J Cardiothorac Surg 2015;48:e92-4.
2. Cano JR, Escobar FH, Alonso DP, et al. Reconstruction of the anterior chest wall with a 3-dimensionally printed biodynamic prosthesis. J Thorac Cardiovasc Surg 2018;155:e59-60.
3. Wen X, Gao S, Feng J, et al. Chest-wall reconstruction with a customized titanium-alloy prosthesis fabricated by 3D printing and rapid prototyping. J Cardiothorac Surg 2018;13:4.
4. Okereke IC. Is 3-dimensional printing the right fit for your reconstruction?. J Thorac Cardiovasc Surg 2018;155:e61-2.
5. Aranda JL, Novoa N, Jiménez MF. Surgical implantation of the prosthesis. Asvide 2019;6:252. Available online: http://www.asvide.com/watch/32937
6. Rodríguez M, Jiménez MF, Hernández MT, et al. Usefulness of conventional pleural drainage systems to predict the occurrence of prolonged air leak after anatomical pulmonary resection. Eur J Cardiothorac Surg 2015;48:612-5.

doi: 10.21037/acr.2019.08.01
Cite this article as: Aranda JL, Novoa N, Jiménez MF. Thoracic customized modular titanium-printed prosthesis. AME Case Rep 2019;3:35.