

# Point-of-care computer-assisted design and manufacturing technology and its utility in post-traumatic mandibular reconstruction: An Australian public hospital experience

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Aaron C Kovacs<sup>ID</sup> and Tran-Lee Kaing

## Abstract

Application of load-bearing osteosynthesis plates is the current gold-standard management for complex mandibular fractures. Traditionally, this has required a transcutaneous submandibular approach, carrying with it the risk of damage to the facial nerve and obvious extraoral scarring. The existing literature describes the use of computer-assisted design and manufacturing technology through external vendors to aid transoral mandibular reconstruction. However, the reliance on third-party manufacturers comes with significant drawbacks, notably increased financial costs and manufacturing delays. We describe our experience in using point-of-care three-dimensional-printed surgical models to aid with the application of mandibular reconstruction plates. Utilising a virtual three-dimensional reconstruction of the patient's preoperative computed tomography facial bones, we fabricate a custom model of the patient's mandible with the department's in-house three-dimensional printer. Stock plates are subsequently pre-bent and adapted to the three-dimensional model, with plate and screw position marked and screw lengths measured with callipers. By using a custom three-dimensional-printed surgical model to pre-contour the plates, we are able to position stock reconstruction plates via a transoral approach. Moreover, our unit's utilisation of in-house computer-assisted design and manufacturing software and hardware allows us deliver a same-day turnaround for both surgical planning and performing the operation. Patient-specific surgical planning guides can facilitate the safe and efficient transoral application of mandibular reconstruction plates. Moreover, the use of point-of-care computer-assisted design and manufacturing technology ensures timely and cost-effective manufacturing of the necessary biomodel.

## Keywords

Computer-assisted design/manufacturing, three-dimensional printing, transoral, mandible fracture, mandible reconstruction

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## Introduction

Application of load-bearing osteosynthesis plates is the current gold-standard management for complex mandibular fractures.<sup>1</sup> Traditionally, this has required a transcutaneous submandibular approach, carrying with it the risk of damage to the facial nerve and obvious extraoral scarring.<sup>2</sup> Previous case reports<sup>3–5</sup> describe the use of computer-assisted design and manufacturing (CAD/CAM) technology through external vendors to aid transoral mandibular reconstruction. However, the reliance on third-party manufacturers comes with significant drawbacks, notably increased financial costs and manufacturing delays.<sup>6,7</sup>

Using a case of complex mandibular fracture non-union, we will illustrate our approach to producing point-of-care

three-dimensional (3D)-printed surgical models to aid with the application of mandibular reconstruction plates. We use a custom 3D-printed surgical model to pre-contour the plates, allowing them to be positioned via a transoral approach. Moreover, our unit's utilisation of in-house CAD/CAM software and hardware allows us deliver a same-day turnaround for both surgical planning and performing the operation.

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Department of Oral and Maxillofacial Surgery, Royal Perth Hospital, Perth, WA, Australia

### Corresponding Author:

Aaron C Kovacs, Department of Oral and Maxillofacial Surgery, Royal Perth Hospital, Victoria Square, Perth, WA 6000, Australia.  
Email: aaronckovacs@gmail.com



We propose that the use of patient-specific surgical planning guides can facilitate the safe and efficient transoral application of reconstruction plates in mandibular fractures where load-bearing osteosynthesis is indicated. Such an approach has the potential to reduce operating time, minimise risk to the facial nerve and improve aesthetic outcomes. Moreover, the use of point-of-care CAD/CAM technology ensures timely and cost-effective manufacturing of the necessary biomodel.

## Case report

A 31-year-old Aboriginal woman presented to a regional Western Australian emergency department following alleged assault, reportedly involving being kicked in the face with steel-capped boots. This was on a background of previous assault and multiple prior facial injuries, including previously treated right parasymphiseal and left angle fractures managed with miniplate fixation 8 years ago. She was a current smoker with a 10 pack-year history.

Her primary complaint was of lower jaw pain and malocclusion. Examination revealed gross right-sided lower facial deformity, with obvious anterior open bite and premature occlusal contact on the right. Imaging demonstrated left body and right angle fractures of her mandible without other maxillofacial or intracranial injuries.

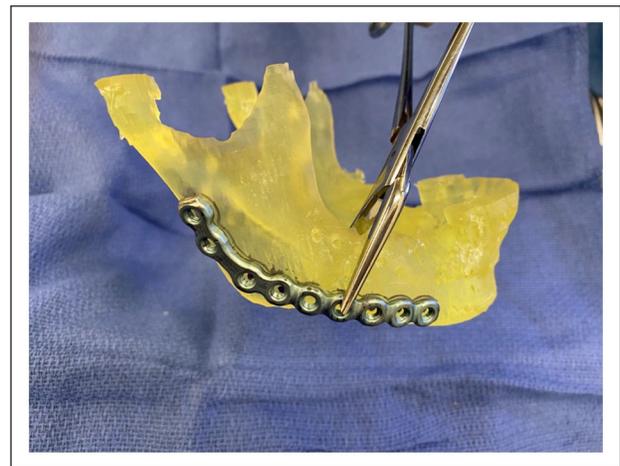
She was transferred to a tertiary trauma centre for definitive management, where she underwent transoral open reduction with miniplate fixation and removal of loose screw from her old parasymphiseal fixation. Her postoperative imaging was satisfactory. As per management of patients from rural and remote communities, she was reviewed face-to-face 1 week postoperatively and then transferred back home.

On review, 3 months postoperatively, the patient reported persistent subjective malocclusion, with the sensation that her lower jaw was 'loose' when chewing. She admitted to further facial trauma during her recovery. There were also concerns regarding her adherence to postoperative instructions. Examination revealed some swelling with tender parasymphiseal region on palpation and movement. The left parasymphiseal metalware was exposed through dehiscence of the intraoral surgical wound. Repeat imaging confirmed a fracture non-union (Figure 1). In light of possible poor patient compliance, smoking and history of repeated alleged assaults with facial trauma, the decision was made to admit her and proceed with definitive load-bearing fixation.

On the morning of the planned afternoon surgery, utilising a virtual 3D reconstruction of the patient's preoperative computed tomography (CT) facial bones, we fabricated a model of the patient's mandible with the department's in-house digital light processing (DLP) 3D printer (PRO 4K; Asiga, Alexandria, NSW, Australia), printed from a generic liquid photopolymer resin. The virtual reconstruction was exported as a \*.stl file using the ProPlan CMF® surgical



**Figure 1.** Orthopantomogram 3 months following surgery demonstrating fracture non-union.

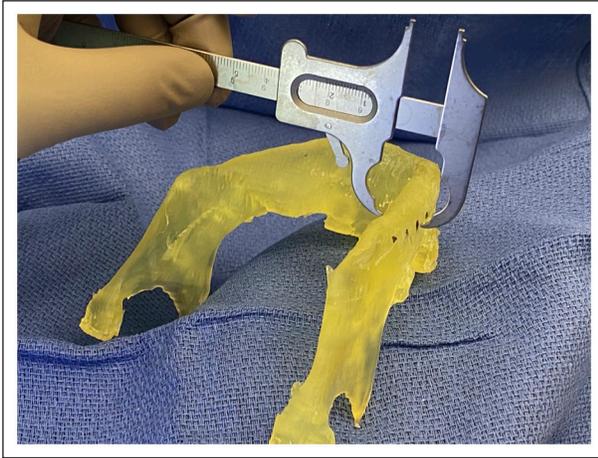


**Figure 2.** Pre-bent 2.5-mm reconstruction plate at right angle.

planning software package (DePuy Synthes, Raynham, MA, USA), and subsequently prepared for printing using Asiga Composer.

Two 2.5-mm load-bearing reconstruction plates (MatrixMANDIBLE™; DePuy Synthes) were pre-bent and adapted to the 3D model (Figure 2). The plate and screw positions were marked on the biomodel and positioned to ensure no interference with previous hardware or screw holes. Bicortical screw lengths were premeasured on the model using callipers (Figure 3).

Surgery was performed via bilateral transoral vestibular incisions. The non-union site was exposed, and loose existing hardware was removed and the area debrided. The mandible was manually held in occlusion. The drill guide was screwed into the locking plates to maintain a perpendicular angle. The plates were subsequently fixed using eight bicortical locking screws each, aided by buccal trocar (Figure 4). No other extraoral incisions were required. Post-reduction and fixation occlusion was satisfactory. The patient was discharged on postoperative day 1 after adequate appearances on postoperative orthopantomogram (Figure 5) and CT (Figure 6).



**Figure 3.** Calliper being used to premeasure length of necessary bicortical screws.

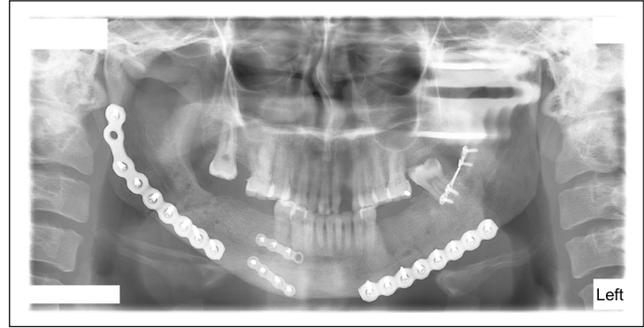


**Figure 4.** Parasymphyseal plate in situ at lower border via vestibular incision.

The patient was well on review at both 1 and 2 weeks postoperatively, with resolution of her malocclusion. She warrants close ongoing follow-up in view of her persistent smoking and previous history of wound breakdown; however, at 3 months postoperatively, she was unfortunately lost to follow-up.

## Discussion

Load-sharing osteosynthesis is the gold standard of management for uncomplicated mandibular fractures;<sup>1</sup> however, in



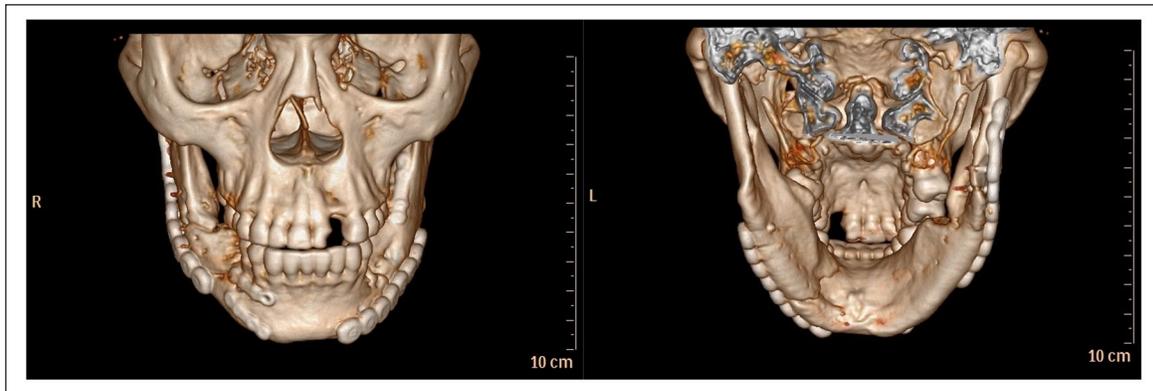
**Figure 5.** Postoperative orthopantomogram.

cases of comminuted fractures and atrophic edentulous mandibular fractures, heavy reconstruction plates using load-bearing principles are necessitated and typically are placed via a transcutaneous submandibular approach.<sup>8</sup> A transcutaneous approach offers greatest access and visualisation of the fractured mandible while minimising handling of the mental nerves, allowing access to fix these larger plates on the lower border of the mandible and bicortical screws.<sup>2</sup> However, this comes with the significant drawback of necessitating a much larger extraoral scar, longer operating time, and risking damage to the marginal mandibular branch of the facial nerve.<sup>2</sup>

Being able to reliably employ a primarily intraoral approach for such cases would have the potential to reduce operating time, minimise surgical complications and improve aesthetic outcomes.<sup>8</sup> Challenges with load-bearing fixation using reconstruction plates via a transoral approach include appropriate visualisation and access, ability to bend a heavy plate to be well adapted to the contour of the mandible, and ability to place bicortical screw both at the optimal angle (perpendicular) and at the correct length.

Transoral application of mandibular reconstruction plates is not without precedent, although its description in the literature is sparse. Probst et al.<sup>9</sup> found success with the use of pre-contoured mandibular reconstruction plates (MatrixMANDIBLE™ Preformed Reconstruction Plates; Synthes Maxillofacial, Paoli, PA, USA), allowing transoral application and fixation in 10 patients requiring load-bearing osteosynthesis of the mandible. In these cases, the curved preformed shape of the plates allowed them to be threaded underneath the mental nerve loops and placed at the lower border of the mandible.<sup>8</sup> However, such a technique accepts that the plate is not perfectly adapted to the patient's individual anatomy, which otherwise can be addressed by the use of a biomodel and pre-bending the plates, or patient-specific plate.

Virtual surgical planning (VSP) is used in elective and semi-elective oral and maxillofacial surgical cases including orthognathic surgery, tumour resection and reconstruction, and secondary management of post-traumatic deformities.<sup>10</sup> The use of this software in virtual planning and fabrication of patient-specific guides and implants has revolutionised these areas of care, greatly improving workflow efficiency



**Figure 6.** Postoperative CT 3D virtual reconstruction.

and reducing treatment planning and operating times.<sup>11–13</sup> There is growing evidence to support that it increases surgical accuracy and reduces operating and ischaemia time.<sup>13–16</sup> This technology is less frequently used in the acute trauma setting.

In oral and maxillofacial surgery, 3D printing technology has seen widespread interest and uptake due to its ability to reproduce complex patient-specific bony anatomy with high degrees of accuracy.<sup>17</sup> Patient-specific surgical guides offer useful tactile feedback inherently absent from conventional two-dimensional (2D) imaging and 3D virtual models. The use of 3D-printed guides may even offer economic benefit, reducing operating theatre costs by shortening average procedure times; one meta-analysis of orthopaedic and maxillofacial surgical cases identified a mean 23 min time saved per procedure.<sup>18</sup>

Beyond 3D printing, VSP can be utilised along with computer numerical control (CNC) milling to fabricate patient-specific instruments, such as custom reconstruction plates.<sup>5</sup> While milled plates are stronger and allow for greater customisation than pre-bent generic plates, they are also more expensive and require longer manufacturing times.<sup>5</sup> Wang et al.<sup>3</sup> described the use of this technology for milling of a pre-contoured, patient-specific reconstruction plate in a patient with bilateral edentulous mandibular fracture. Similar to the technique employed by Probst et al.<sup>9</sup> and in our procedure, the curved plate allowed for transoral positioning and fixation via bilateral vestibular incisions. In contrast to our case, VSP and plate manufacturing was performed by a commercial vendor and was not available for use until at least 5 days after submission.

It is now commonplace for external, commercial vendors to manufacture patient-specific instruments with the oversight of bioengineers, although this comes with significant financial impact.<sup>6</sup> A 2014 study<sup>19</sup> calculated a mean additional cost of €2545.36 per maxillofacial reconstruction case whenever outsourced CAD/CAM technology was utilised. Consequently, being able to develop in-house, point-of-care

devices has the potential to markedly reduce costs for the benefit of patients and surgical units. Indeed, Oppenheim<sup>20</sup> identified a cost-saving of 50% when producing point-of-care guides for dental implants compared with those outsourced to an external dental laboratory.

The manufacturing delay associated with external vendors is another limitation of 3D-printed surgical guides and other patient-specific instruments, something that likely inhibits its uptake in the acute trauma setting.<sup>7</sup> In a series of five patients undergoing acute mandibular trauma reconstruction, the average interval between injury and availability of an externally milled custom plate was 7 days.<sup>5</sup>

By utilising an in-house 3D printer for construction of a point-of-care surgical guide and model, we have been able to efficiently use generic reconstruction plates pre-bent with accuracy. We have also been able to deliver the surgery on the same day with shorter operating time. The use of a 3D-printed surgical model has allowed us to safely utilise a largely transoral approach to place a well-adapted reconstruction plate at the lower border with perpendicular bicortical locking screws measured to length, where traditionally this would not have been considered feasible. With the increasing accessibility and affordability of point-of-care CAD/CAM software and hardware, we are likely to see an expanding range of applications for this technology in oral and maxillofacial surgery, and indeed surgery more broadly.

## Conclusion

Our case and other comparable reports in the literature highlight that load-bearing mandibular reconstruction plates can be safely and effectively positioned via a predominantly transoral approach. This method allows access to the lower border for placement of a reconstruction plate with bicortical locking screws using load-bearing principles. Moreover, our utilisation of an in-house 3D printer highlights the increasing accessibility of this technology and its potential to simplify surgical planning without being reliant on external vendors.

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## Ethics approval

Our institution does not require ethical approval for reporting individual cases or case series.

## Informed consent

Written informed consent was obtained from the patient(s) for their anonymised information to be published in this article.

## ORCID iD

Aaron C Kovacs  <https://orcid.org/0000-0002-2684-942X>

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