DOI: 10.1308/rcsfdj.2025.19

# In-house 3D printing in a New Zealand oral and maxillofacial surgery centre: why, when and how?

In-house 3D printing is revolutionising oral and maxillofacial surgery, offering cost-effective, patient-specific solutions. A new study from Waikato Hospital examines its impact on surgical outcomes, efficiency, and sustainability.

**Denty Gozali** House Officer
**Arun Majumdar** Consultant Oral and Maxillofacial Surgeon
**Jacques Glover** Non-training Registrar
**Michael Williams** Maxillofacial Technician
**Mustafa Mustafa** Maxillofacial Technician
**Thasvir Singh** Consultant Oral and Maxillofacial Surgeon
Waikato Hospital, Hamilton, New Zealand

**dentygozali@gmail.com**

Rapid prototyping has long been involved in medical fields, with its first use in oral and maxillofacial surgery (OMFS) dating back to 1990.[1] The term covers a wide range of techniques and processes, usually of additive nature, to create physical models. The most commonly discussed process is three-dimensional (3D) printing, which utilises computer-aided design to produce 3D models formatted into thin horizontal layers, printed sequentially layer by layer. This allows the creation of accurate models in a time-effective manner while offering sustainability benefits over traditional manufacturing methods. The *FDJ* has previously published a detailed article highlighting the benefits of 3D printing in dentistry.[2]

Although initial usage was predominantly through complex and expensive outsourced services requiring specialist training, recent advances in technology have resulted in better access to the software and hardware services that are necessary to undertake 3D printing in the medical field. In today's practice of precision medicine and individualised therapies, patient-specific anatomical models that are 3D printed are becoming helpful tools for the medical community, with wider applications. Customised, sterilisable and biocompatible parts are increasingly in demand, leading to the creation of biomodels, surgical cutting guides and patient-specific implants in OMFS.

In-house 3D printing enables rapid creation of custom models, enhancing innovation and resource efficiency; this significantly reduces waste, energy consumption and emissions while improving service performance and sustainability.[3,4] This paper will focus on the in-house 3D printing of biomodels in OMFS (including its tangible benefits in terms of patient outcomes – either due to surgical success or improved patient understanding)[3] as this was the extent of the 3D printing capability at Waikato Hospital in New Zealand between 2020 and 2023.

The literature shows that there are multiple applications for which a printed biomodel can be used, as summarised in Figure 1, from preoperative multidisciplinary surgical planning to improved patient understanding about disease and deformity, thereby improving patient consent and communication, and managing patient expectations.[4–7] It allows surgeons to access tools and implants to suit certain patient-specific requirements by offering various unique possibilities.

In the field of OMFS, 3D printing has expanded to include complex maxillofacial trauma reconstruction, head and neck oncology, orthognathic surgery and other areas.[4] Currently, 3D printing is finding new applications in tissue engineering, complex temporomandibular joint replacement, trauma surgery, pathology-induced anomalies and facial asymmetry correction.[8,9] Figure 2 illustrates the uses of printed biomodels in OMFS in three main areas, from preoperative planning to virtual prints, including (but not limited to) surgical guides, prostheses, contour models, implants and plate bending.

Waikato Hospital is a level 1 trauma centre based in the North Island of New Zealand. Being one of the few hospitals in New Zealand with on-call OMFS support, it provides the full range of acute and elective OMFS services to approximately one million people (a fifth of the New Zealand population).[10] At the start of 2020, the Waikato OMFS department acquired a 3D printer and the appropriate software to begin in-house printing of biomodels. Prior to this, cases for which these were deemed necessary were sourced internationally, originating either from Switzerland or Malaysia.

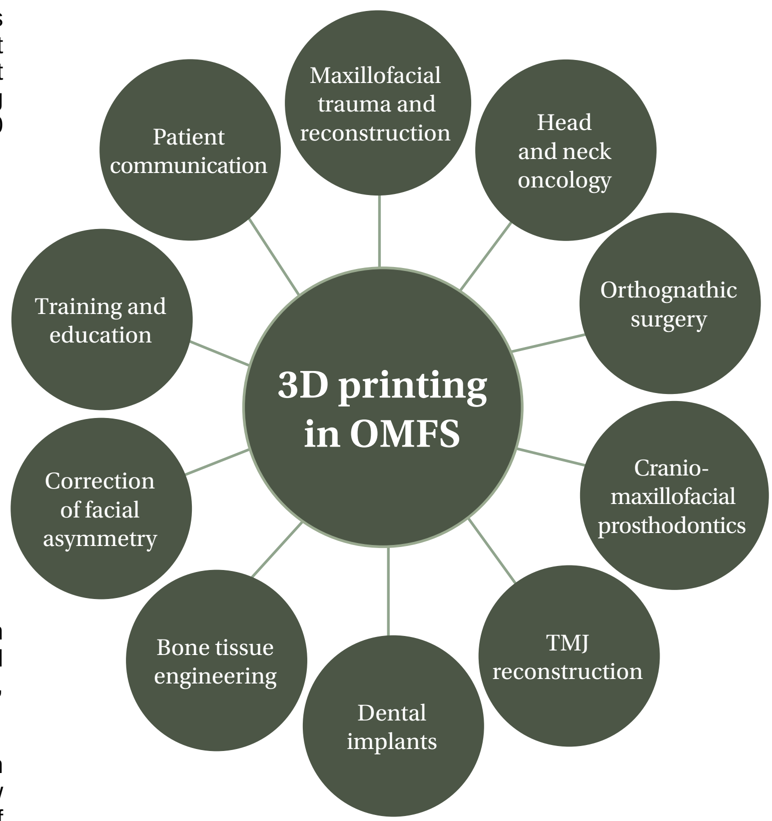
To date, there have been no studies on the long-term benefits of 3D printing in OMFS and it is unclear how useful it is to have an in-house 3D printing facility at hospitals as opposed to outsourcing these services. The aim of this study was to complete a retrospective audit of the OMFS cases that utilised the first in-house 3D printer between 2020 and 2023, and to identify the value of such a service to the Waikato Hospital OMFS department.

## Methods

### *In-house 3D printing biomodel process*

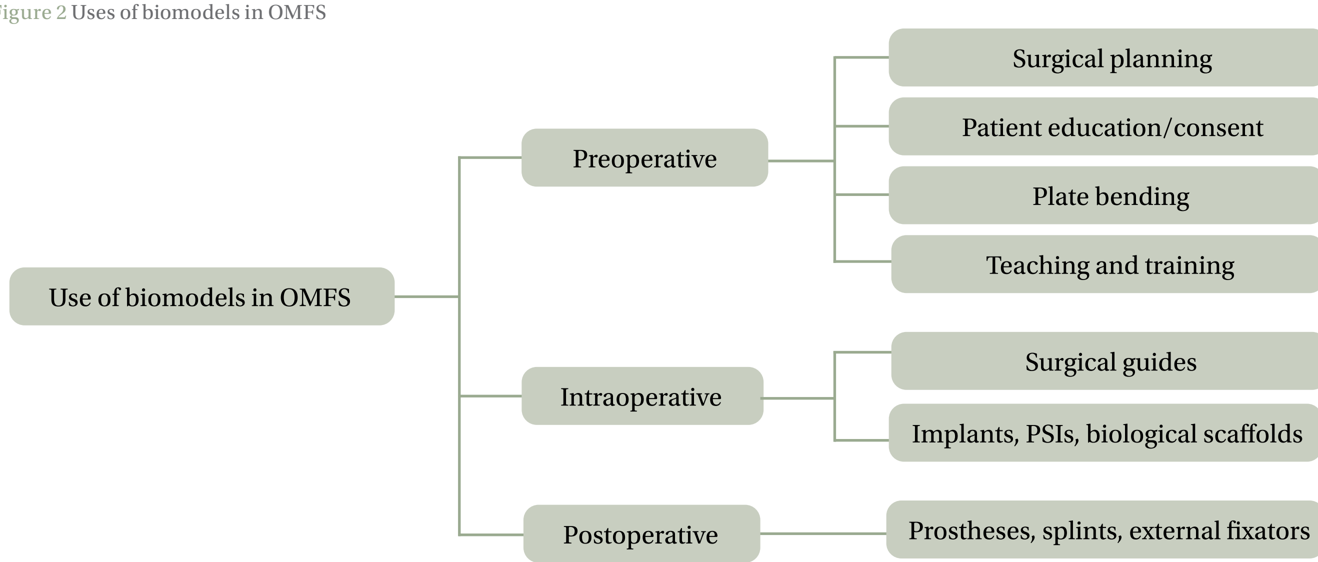
The typical workflow in the Waikato OMFS department varies depending on the case. The patient is initially assessed by our team with appropriate triage to ensure that there are no acute issues and that the case is suitable for early planned treatment. If so, the patient will often return to the OMFS department for specialist review, and for imaging analysis (cone beam computed

Figure 1 Applications of biomodels in OMFS (modified with permission from Hadad *et al*)[20]




OMFS = oral and maxillofacial surgery; TMJ = temporomandibular joint

Figure 2 Uses of biomodels in OMFS




OMFS = oral and maxillofacial surgery; PSIs: patient-specific implants

tomography/medical grade computed tomography) to visualise the anatomy of the head and neck to obtain a diagnosis.

When a biomodel is needed, this imaging is assessed by maxillofacial prosthetic technicians, who convert it to an STL file format via 3D printing software (ProPlan CMF™; Materialise, Leuven, Belgium). The STL file is assessed and a 3D reconstruction of the two-dimensional images is created. Once designed and approved by the software, the rapid prototyping via the 3D printer (Form 3L; Formlabs, Somerville, MA, US) begins, creating a highly accurate biomodel. Figure 3 shows the in-house 3D printing process and the final biomodel fabrication.

*Data retrieval*
Data were sourced through retrospective analysis of the cases for which 3D biomodels had been printed. The printing history of the models was analysed, along with the respective pre- and postoperative patient notes. Information was then corroborated with the 3D printing logs from the maxillofacial prosthetic team to ensure accuracy. Variables investigated included the number of biomodels printed, the site and clinical indications for producing the biomodels. These data were kept in a secure spreadsheet.

*Statistical analysis*
Variables were assessed with the assistance of the Waikato Hospital statistical team. After checking and grouping the data, summary statistics were calculated. Chi-squared tests were employed to investigate differences with regard to the types of biomodels printed and the indications for printing. Data were analysed using Excel® (Microsoft, Redmond, WA, US) and SPSS® Statistics version 29 (IBM, New York, US). A *p*-value of <0.05 was deemed statistically significant.

## Results
Table 1 summarises the information on the number of biomodels printed, the types of biomodel produced, the indications for printing the biomodels and their clinical uses. Over the four-year study period, 474 biomodels were printed for 321 different patients. The first year had the largest workload, with 166 biomodels printed, whereas the following years averaged 103 biomodels per year.

Figure 3 Outline of workflow at Waikato Hospital's oral and maxillofacial surgery department, with 3D imaging system (cone beam computed tomography/medical grade computed tomography) for preoperative imaging (A, B), fabrication of biomodels using the in-house 3D printer (C) and postoperative imaging of left orbital reconstruction (D)

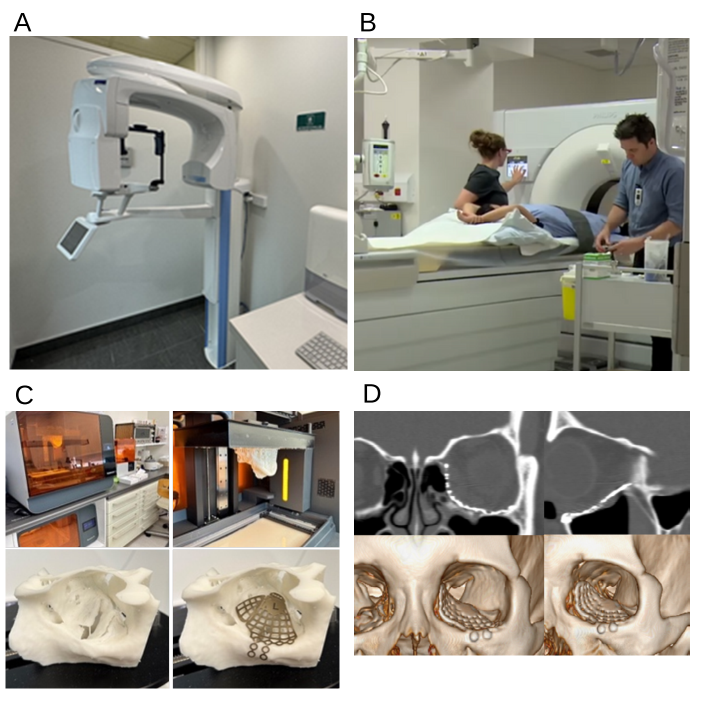


Table 1 In-house 3D printing utilisation in Waikato Hospital oral and maxillofacial surgery department

| | *n* |
|---|---|
| *Year* | |
| 2020 | 166 (35%) |
| 2021 | 103 (22%) |
| 2022 | 101 (21%) |
| 2023 | 104 (22%) |
| *Types of biomodel* | |
| Orbit/zygomaticomaxillary complex | 282 (60%) |
| Maxilla + midface | 76 (16%) |
| Mandible | 72 (15%) |
| Maxilla + mandible | 32 (7%) |
| Dental | 6 (1%) |
| Facial prosthesis | 6 (1%) |
| *Clinical indications for biomodels* | |
| Trauma | 354 (75%) |
| Pathology/reconstruction | 71 (15%) |
| Orthognathic | 22 (5%) |
| Facial prosthesis | 10 (2%) |
| Infection | 10 (2%) |
| Cleft/craniofacial | 7 (2%) |
| *Clinical uses of biomodels* | |
| Plate bending | 369 (78%) |
| Surgical planning | 70 (15%) |
| Implant/prosthesis planning | 18 (4%) |
| Cleft multidisciplinary team | 7 (2%) |
| Education | 5 (1%) |
| Other/unknown | 5 (1%) |

The orbit/zygomaticomaxillary complex (ZMC) was the most common biomodel type printed (60%), followed by the maxilla/midface (16%) and mandible (15%). There were no significant differences in terms of clinical indications and types of biomodels printed at any time point. Trauma accounted for 75% of the indications for printing, followed by pathology (15%) and orthognathic surgery (5%). The remaining 6% were a combination of other reconstructive reasons, such as cleft dentofacial deformity and chronic bone infection cases. Three-quarters (78%) of the biomodels were used for plate bending, and a fifth (19%) for interdisciplinary surgical planning.

There was a strong dependence between the type of biomodel printed and the clinical uses for printing ($\chi^2$=278, $p$<0.001). When considering only the trauma cases, 279 biomodels were for the orbit/ZMC region (79%); this was followed by the maxilla/midface (14%) and mandible (6%). The vast majority of biomodels printed for trauma were for preoperative plate bending purposes (95%).

## Discussion

This retrospective study investigated the utility and value of the in-house 3D printer in the OMFS department at Waikato Hospital in New Zealand. Trauma accounted for three-quarters (75%) of our indications while remaining indications were a combination of orthognathic surgery, oncology and other reconstructive reasons. Almost all (95%) of the biomodels printed for patients with trauma were for the purposes of preoperative plate bending and this result was statistically significant ($p$<0.001).

Multiple studies have shown advancements in personalised treatment through accurate surgical planning and custom implants, transforming the healthcare field with improved patient outcomes.[3,5–8,11] The rapid creation of 3D replicas of patient anatomy provides tangible and precise representation of injury, aiding preoperative planning, surgical simulation and patient communication. This demonstrates the potential for enhancing surgical outcomes when accompanied with good surgical skills, as well as patient participation in their treatment, thereby improving satisfaction.

In our daily practice, 3D printed anatomical biomodels are useful for preoperative planning, patient communication, intraoperative guidance, teaching and training purposes. The software and STL file also allow 3D preoperative visualisation and complex surgical planning virtually, with the whole multidisciplinary team involved in the care of complex trauma, oncology, orthognathic, cleft deformity, and head and neck pathology cases. Recent studies have shown that confidence in surgical planning has increased and education has benefitted from the use of this technology.[10,12,13] It enables both surgeons in training and medical students to engage with anatomy and view procedures that would otherwise be inaccessible, which greatly expands the scope of learning for the future. Custom implants and guides can also be fabricated to fit individual patient anatomy.

The range of acute traumatic injuries that the OMFS team deals with and the requirement to shorten the interval from preoperative assessment to hospitalisation and surgical treatment call for the flexibility that the 3D printing biomodelling process offers. With an in-house service, the fabrication of the biomodel is completed within two days, which is a reasonable amount of time to treat the majority of OMFS injuries in hospitals using mostly open reduction and fixation.

The findings of the present study are in agreement with other studies.[14–16] From mandibular fractures and trauma to midface/ZMC and even to orbital reconstruction cases, 3D printing enables the creation of anatomical biomodels and pre-bending of fixation plates. In our clinical setting, the most common type of biomodel produced, namely for reconstruction of the orbit, has evolved by mirroring intact contralateral anatomy (instead of using the fractured orbit) to serve as the basis for restoring the anatomical defect (Figure 3).[5,16] This is achieved with software such as Mimics (Materialise) or Freeform Plus (3D Systems, Rock Hill, SC, US), along with milling processes for the patient-specific implant design if required, although this is yet to be implemented in our laboratory. Preoperative 3D evaluation of the anatomy has become the accepted standard of care, enhancing accuracy, and has proved time-efficient.[17,18]

3D imaging together with computer-assisted surgical simulation and planning are now routinely employed for assessing

Table 2 Retrospective comparison of biomodel printing costs at Waikato Hospital in New Zealand

| In-house printing costs | Outsourcing costs |
|---|---|
| 3D printer ($9,000–$30,000) | $150,000 spent per year on average in outsourcing to a local biomodel printing service |
| Software ($55,000/year) | |
| Material costs ($10–$15/kg) | |
| Time: ½ hour to design and 1½ hours to print | Time: 2-week turnover |
| Technician ($25–$30/hour) | |
| Average cost for orbit: $35–$50 | Average cost for orbit: $1,280 (excluding GST figures) |

craniomaxillofacial anatomy, thereby improving surgical success prediction in orthognathic surgery, oncology and other pathology-induced abnormalities. 3D printing for these applications has already been documented in several studies.[3,6,9,11] In this paper, we have presented the major applications for in-house 3D printed biomodels, as summarised in Table 1, allowing for the additional utilisation of these 3D data sets beyond mere diagnosis. Preoperative plate bending and surgical guides are the most common uses, with the aim of facilitating precise implant placement, as predicted by preoperative surgical planning. 3D printed splints, wafers and guides are known to be utilised in orthognathic surgery. These help the surgeon to position the osteotomy lines correctly, orientate the implant screws in pre-determined angulation on the biomodel, maintain the maxilla and mandible in the intended occlusal relation, and arrange osteotomised bone segments, in line with engineering and regenerative medicine approaches.[19]

## Conclusions

This study demonstrates the versatility of an in-house 3D printing service and the wide variety of cases for which it can be used, from trauma to head and neck pathology, and comprehensive oral and craniomaxillofacial reconstruction. It has significantly reduced our need to outsource services. As a level 1 trauma centre in the New Zealand Waikato region offering the full range of contemporary OMFS, our in-house service has been beneficial in managing our emergency and elective workload.With an average of 120 models produced per year, it has saved the Waikato Hospital OMFS department approximately NZD$600,000 and treatment time over the first four years (Table 2). These cost savings are hugely important given the current constrained resources in the public healthcare systems of many advanced economies. This technology could also lower carbon dioxide emissions, and promotes the use of sustainable materials and energy-efficient practices. We envisage expansion of this useful service across all maxillofacial departments and laboratories as well as collaboration with biomedical engineers to benefit the wider specialist surgical services.

Within the limitations of this retrospective study, it can be concluded that considerable cost reductions can be realised by implementing an in-house 3D printing service. The advantages in OMFS are evident and well established, and include innovation, efficiency, cost-effective production, sustainability and patient-specific flexibility. In addition, it fosters continuous development, a better surgical workflow and improved patient understanding. With further advancements, this technology is going to become more user-friendly and versatile. For this reason, familiarisation with 3D printing and its full potential in surgery is worthwhile. More research is warranted to investigate qualitatively and quantitatively the long-term economic benefits for clinical care achieved from utilisation of this in-house 3D biomodel printing service.

## Acknowledgements

We would like to thank the Department of Oral and Maxillofacial Surgery at Waikato Hospital for providing the support and facilities to undertake this study. Thanks are also due to Rachel Clarke from the Waikato Hospital statistical team for her assistance in data analysis. Finally, we are grateful to Dr Henrique Hadad for granting us permission to modify the diagram from his article (Figure 1).[20]

The material in this paper was presented at the Annual Scientific Meeting of the New Zealand Branch of the Australian and New Zealand Association of Oral and Maxillofacial Surgeons held in Queenstown, August 2024.

## *References*

1. Arvier JF, Barker TM, Yau YY *et al*. Maxillofacial biomodelling. *Br J Oral Maxillofac Surg* 1994; **32:** 276–283.
2. Hems E, Knott NJ. 3D printing in prosthodontics. *FDJ* 2014; **5:** 152–157.
3. Louvrier A, Marty P, Barrabé A *et al*. How useful is 3D printing in maxillofacial surgery? *J Stomatol Oral Maxillofac Surg* 2017; **118:** 206–212.
4. Modgill V, Balas B, Chi M *et al*. Knowledge domain and innovation trends concerning medical 3D printing for craniomaxillofacial surgery applications: a 30-year bibliometric and visualized analysis. *Craniomaxillofac Res Innov* 2023; **8**.
5. Graham DO, Lim CG, Coghlan P, Erasmus J. A literature review of rapid prototyping and patient specific implants for the treatment of orbital fractures. *Craniomaxillofac Trauma Reconstr* 2022; **15:** 83–89.
6. Ghai S, Sharma Y, Jain N *et al*. Use of 3-D printing technologies in craniomaxillofacial surgery: a review. *Oral Maxillofac Surg* 2018; **22:** 249–259.
7. Salgueiro MI, Stevens MR. Experience with the use of prebent plates for the reconstruction of mandibular defects. *Craniomaxillofac Trauma Reconstr* 2010; **3:** 201–208.
8. Gellrich NC, Ehrenfeld M. Computer assistance in modern craniomaxillofacial surgery. *Innov Surg Sci* 2023; **8:** 135–136.
9. Assari A. Usability of three-dimensional printing in maxillofacial surgery: a narrative review. *Open Dent J* 2023; **17:** e187421062304190.
10. New Zealand Government. Population. https://www.stats.govt.nz/topics/population (cited March 2025).
11. Matias M, Zenha H, Costa H. Three-dimensional printing: custom-made implants for craniomaxillofacial reconstructive surgery. *Craniomaxillofac Trauma Reconstr* 2017; **10:** 89–98.
12. Yashavanth Kumar DS, Christopher SD, Mallegowda H *et al*. Three-dimensional printing in the field of oral and maxillofacial surgery. *Natl J Maxillofac Surg* 2022; **13(Suppl 1)**: S19–S23.
13. Blanchard J, Koshal S. Augmented reality: a new perspective in dental education. *FDJ* 2024; **15:** 68–72.
14. Kokosis G, Davidson EH, Pedreira R *et al*. The use of computer-aided design and manufacturing in acute mandibular trauma reconstruction. *J Oral Maxillofac Surg* 2018; **76:** 1,036–1,043.
15. Longeac M, Depeyre A, Pereira B *et al*. Virtual surgical planning and three-dimensional printing for the treatment of comminuted zygomaticomaxillary complex fracture. *J Stomatol Oral Maxillofac Surg* 2021; **122:** 386–390.
16. Xue R, Lai Q, Sun S *et al*. Application of three-dimensional printing technology for improved orbital-maxillary-zygomatic reconstruction. *J Craniofac Surg* 2019; **30:** e127–e131.
17. King BJ, Park EP, Christensen BJ, Danrad R. On-site 3-dimensional printing and preoperative adaptation decrease operative time for mandibular fracture repair. *J Oral Maxillofac Surg* 2018; **76:** 1950.e1–1950.e8.
18. Jansen J, Schreurs R, Dubois L *et al*. The advantages of advanced computer-assisted diagnostics and three-dimensional preoperative planning on implant position in orbital reconstruction. *J Craniomaxillofac Surg* 2018; **46:** 715–721.
19. Zoabi A, Redenski I, Oren D *et al*. 3D printing and virtual surgical planning in oral and maxillofacial surgery. *J Clin Med* 2022; **11:** 2385.
20. Hadad H, Boos Lima FB, Shirinbak I *et al*. The impact of 3D printing on oral and maxillofacial surgery. *J 3D Print Med* 2023; **7**: 3DP007.