

EDITORIAL

Head and neck skeletal reconstruction before and since virtual surgical planning

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The attributes of curiosity, a measure of restlessness if not recklessness, a healthy ego, a deep suspicion of conventional wisdom and a disdain for the status quo are factors which drive innovation. For several decades from the 1970s onwards Australia, and Melbourne in particular, fostered an era of innovators—from Bernard O'Brien and Wayne Morrison at St Vincent's Hospital to Ian Taylor and Russell Corlett at the Royal Melbourne Hospital—who pioneered the field of microsurgery and took their place on the world stage. Their work is intricately tied to the story of mandibular reconstruction following resection of head and neck cancers, which represents one of the greatest challenges for the reconstructive surgeon.

While the development of microsurgery allowed the first free tissue transfers to be performed, these were still predominantly soft tissue flaps and mandibular reconstruction still relied on pedicled vascularised rib flaps. The first anatomical description and successful execution of the fibular bone flap for limb reconstruction and later the deep circumflex iliac artery bone flap for mandibular reconstruction^{1,2} by Taylor and Corlett in the 1970s, facilitated the transition from pedicled to free flaps for mandibular reconstruction. Further refinements in 1983 by Chen and Yan, who described the osseocutaneous modification of the fibula,³ and in 1989 by David Hidalgo, who applied the fibular flap for mandibular reconstruction, increased the utility of the flap.⁴ Fu Chan Wei's series of mandibular reconstruction with the osseo-musculo-septocutaneous fibular flap

demonstrated how a variety of composite defects could be reconstructed using one flap.⁵ Turning a bone with a linear morphology into the curvature of the native mandible while maintaining vascularity requires rigorous planning.⁶ The first two decades of planning was 'analogue', based on preoperative radiological measurements and templating of the defect intraoperatively. Such techniques involved a trial-and-error approach by the clinician to adjust the fibular osteotomies to obtain the required neo-mandibular shape. Placement of this bone in a three-dimensional (3D) space with the correct pitch, yaw and tilt required a measure of genius or, more commonly, luck. There was a lengthy and unforgiving learning curve and reconstructions were susceptible to imprecision and variability in outcomes.⁷⁻⁹ The aim was to restore the continuity of the bony skeleton with

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an emphasis on bony healing and to restore facial contour. The restoration of dentition was a distant afterthought and the ability to retain a prosthesis uncommon. To address this, Rohner in 2000 elegantly described a two-stage technique with osseointegrated dental implants placed into a prefabricated skin-grafted fibular flap (the skin for the neo-gingiva), followed six weeks later by the transfer of the fibula which is osteotomised to obtain the desired mandibular contour and, more importantly, implant position to facilitate dental restoration. The planning required was meticulous and onerous, involving the use of plaster models based on the patient's dental impressions, followed by mounting these models onto a temporomandibular joint articulator, prior to performing the model surgery to simulate the resection and hence the reconstruction.¹⁰

The advent of virtual surgical planning (VSP) markedly advanced the domain of craniofacial surgery, especially in orthognathic surgery and skeletal reconstruction of the head and neck for cancer and trauma. Surgical guides and biomodels are generated through this process, where the surgery is simulated using computer planning software that in turn generates 3D digital models, stored as stereolithography (STL files), that can be used to manufacture the physical guides and models used during surgery.^{11–13} By leveraging high-resolution computed tomography imaging in conjunction with 3D printing technologies, surgeons are able to preoperatively delineate osteotomies and flap positioning with enhanced precision.¹⁴ These technologies facilitate the fabrication of patient-specific stereolithographic cutting guides, positioning jigs and custom-fabricated fixation plates, thereby enabling accurate mandibular resections, reliable fibula segmentation and more efficient intraoperative transfer of the preoperative plan.^{15–17} Collectively, these innovations have augmented the precision, reproducibility and efficiency of head and neck skeletal reconstruction, while mitigating intraoperative variability that would otherwise be heavily influenced by surgeon experience.¹⁸ Additionally as demonstrated most elegantly by Jaw in a Day cases (where patients undergoing resection of their jaw and dentition can have a reconstruction which encompasses skeletal reconstruction and dental prosthesis all in one procedure), digital planning allows the clinician to plan in reverse with the desired outcome (eg dental restoration) influencing the type and position of bony flap placement and more critically, implant placement within the bony flap. Such technologies

make possible a more efficient pathway to dental restoration, which is a key quality of life issue for patients undergoing head and neck cancer surgery.¹⁹ Virtual surgical planning also facilitates the design and placement of custom-made implants, both for reconstruction of defects (such as cranioplasty) and, less commonly, aesthetic cases.²⁰

In contrast to conventional methods that require minimal preoperative preparation, computer-aided planning enables a more detailed analysis of patient-specific anatomy and allows for deliberate, strategic surgical planning. This extended planning phase fosters closer collaboration between the resecting and reconstructive teams. It encourages more comprehensive discussions on osteotomy location, vascular pedicle design and donor site selection, all of which contribute to more individualised, patient-centred care.²¹

Emerging evidence has further demonstrated that the use of patient-specific surgical guides and pre-bent fixation plates in head and neck reconstruction is associated with a statistically significant reduction in operative duration, ischaemia time, postoperative complications and subsequently, the length of stay, underscoring their potential value, particularly for surgeons with less extensive reconstructive experience.^{18,22–35} Unfortunately, many of the available studies are constrained by small cohort sizes, typically ranging from 13–30 cases, which substantially limits the generalisability and external validity of their findings.^{22,36} Virtual surgical planning is limited, especially in cancer and trauma reconstruction, by the lag time between image acquisition, virtual planning and eventual placement of implants, which can vary from days to weeks depending on the complexity of the patient-specific implants. This may preclude the use of this technology.²⁷ There is also an inherent assumption in VSP that biologic systems are inert and do not change over time. This can be problematic, for example, when cancers grow and resection needs change. There is often no capacity to modify the implants if the real time clinical need is found to vary from the virtually planned solution.³⁷

While VSP is done 'in-house' in a few centres in Australia, the majority of VSP currently involves a commercial third party, often with an overseas-based manufacturing centre. For institutions opting to perform in-house computer-aided design/computer-aided manufacturing (CAD/CAM) planning and guide production, several practical factors must be considered. These are

labour and material costs, and the learning curve involved in training surgeons and technical staff to use the necessary software and equipment.³⁸ These challenges are particularly relevant because the upfront investment in an industrial-grade 3D printer is large, especially for centres performing only a small number of mandibular reconstructions annually. Additionally, the rapid pace of technological development means that these printers can quickly become obsolete.³⁹

Commercial VSP adds not just time and cost to the process but also leads to clinician disenfranchisement, as it relies on the clinician's ability to communicate a clinical need to an engineer to produce the requisite product. There is reduced oversight by the clinical teams, which may impact surgical accuracy.⁴⁰ Outsourcing to a rapid prototype modelling company also raises additional considerations, including how to securely transfer patient health information. An ideal VSP process would be able to respond quickly to the needs of the clinician, be modifiable and affordable.³⁹ Augmented reality may have a role in providing part of the answer to this problem, for example, by guiding osteotomies in a fibular flap in order to match a resection defect.

Nevertheless, the principal limitation remains the increased overall procedural cost compared with conventional freehand techniques, compounded by the lack of robust evidence for clear cost-effectiveness. Preoperative imaging, planning and fabrication of cutting guides introduce additional costs, and the balance between these upfront expenditures and potential downstream savings has yet to be clearly defined. Studies have assessed outcomes such as operative duration, hospital length of stay, overall procedural costs and complication rates.^{18,30,39,41,42} However, findings across the literature are inconsistent depending on the healthcare model, expenditure and funding.²⁵

This lack of consensus is further compounded by heterogeneity in study design, outcome measures and healthcare funding models. Moreover, the majority of available data arise from international centres, where cost structures and reimbursement mechanisms differ substantially from those in

Australasia. Importantly, there remains a scarcity of Australian literature specifically addressing the true clinical and financial impact of VSP in head and neck skeletal reconstruction. This needs to be urgently addressed by prospective collection of high-quality data demonstrating the utility of VSP. Without this we stand to lose publicly-funded access to VSP, as suggested by a recent Prosthesis List Post Listing Review performed by the Medical Devices and Human Tissue Advisory Committee. This review highlighted concerns about the way VSP is being used in our healthcare system and what is perceived as a disparity between its intended and actual use. While the review is ongoing, a Stage 2 report supports the notion of limiting access to this technology in the public and thereby the private system as well.⁴³

In summary, VSP is an emerging and exciting adjunct to modern head and neck skeletal reconstruction, particularly when dental reconstruction is required. The current literature, however, is limited and the financial modelling opaque. Widespread uptake, particularly in the public healthcare system, will require detailed prospective studies documenting its financial feasibility and superior clinical outcomes over existing reconstructive techniques.

Conflict of interest

The author has no conflicts of interest to disclose.

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