Computer Guided Surgery for Implant Placement and Dental Rehabilitation in a Patient Undergoing Sub-Total Mandibulectomy and Microvascular Free Flap Reconstruction

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A 58-year-old patient presented with an extensive, destructive, recurrent pleomorphic adenoma occupying the mandibular body and the soft tissues of the mouth and neck. Resection of the mandible from right ramus to left condylar process, and implant rehabilitation in both jaws with fixed bridgework was planned. Comprehensive presurgical prosthetic work up was carried out to record the existing dental relationship and guide all stages of the reconstruction. The jaw was first grafted with a segmented, fibular microvascular free-flap, which was fixed in place with a fixation plate prebent on a Rapid Prototype Anatomical Model of the jaw. Reconstruction with implant supported fixed partial dentures took place to the dental scheme planned preresection, using a computer guided approach to implant placement in the complex and unfamiliar anatomy of the extensively grafted mandible. This approach facilitated and expedited implant surgery such that treatment could take place using a minimally invasive approach relatively soon after surgery, prior to commencement of radiotherapy, and highlights the importance of a multidisciplinary approach to treatment for patients having extensive surgery to the jaws. The patient's personal assessment 2 years post surgery was recorded using 1999 University of Washington Quality of Life Questionnaire.

Key words: fibula free flap, jaw reconstruction, dental implants, anatomical model, computer guided implant surgery

INTRODUCTION

The osseocutaneous fibula flap used to reconstruct large segments of the mandible after resection for cancer[1] has become a routine procedure in orofacial reconstruction. A prospective study concluded the fibula free flap bone graft allows predictable and reliable restoration with conventionally placed dental implants.[2] Although dental rehabilitation is considered to be a significant factor in the assessment of quality of life,[3] such surgery often leaves the patient unable to tolerate conventional dentures, presenting an indication for implant treatment.

The use of rapid prototype models of the jaw permits the prefabrication of fixation plates,[4] greatly facilitating intraoperative positioning of the graft to avoid dental malocclusion, which may result from inaccurate contouring of the reconstruction plate.[5] Computer-guided planning using custom-made surgical drilling guides based on 3-dimensional (3D) computerized tomography (CT) scanning[6] is used increasingly in routine dental implant cases.

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This approach to treatment significantly reduces the deviation between planned and achieved positions, verified in cadaver studies[7,8] on epoxy mandibles[9] comparing preoperative and postoperative scans and supported by successful use in patients.[10,11] An awareness of some of the pitfalls associated with computer-guided surgery may enhance the predictability of the technique.[12]

It is important to note that postoperative radiation therapy is likely to be required in such cases. Although radiation therapy has been considered a contraindication to implant surgery,[12] studies have shown that postoperative radiation therapy does not significantly affect the osseointegration of dental implants placed in native bone during ablative surgery; furthermore, it is suggested that primary implant placement has advantages over secondary implant placement in patients with oral carcinoma.[12,13] These various concepts have been consolidated in a multidisciplinary procedure in which implants were placed in the native mandible using a surgical drill guide.[14] This report describes a fully computer-guided approach to dental implant placement in the unfamiliar environment of the reconstructed neomandible.

Case Report

A 58-year-old woman presented with an extensive, destructive, and expansive cyst-like lesion of the mandibular body, which had greatly distorted the patient's anatomy (Figures 1, 2a and b).

Thirty years earlier the patient had a pleomorphic adenoma of the sublingual gland removed. Recent biopsy of the mandibular, submental, and submandibular masses confirmed a diagnosis of recurrent pleomorphic adenoma occupying the mandibular body and present in the soft tissues of the floor of the mouth and upper neck. Surgical treatment was planned for resection of the mandible from right ramus to left condylar process.

Incidentally, the maxillary dentition was failing, and a large cyst associated with the roots of the anterior teeth was identified.

CT data were processed to enable the fabrication of a rapid prototype anatomic model (RPAM) of the mandible (Figure 3). Surgery was planned on the resin model, and a titanium fixation plate (Synthes Unilock system, Synthes, International) was prebent on another model, which had been trimmed with a hand-piece and acrylic bur to an "idealized" contour (Figure 4).

The patient was referred to the restorative team for presurgical work-up. An immediate maxillary denture was fabricated, as well as a "tooth set-up" for the lower jaw.

All of the maxillary teeth were removed and the associated cyst enucleated (biopsy later confirmed the diagnosis of a large but benign inflammatory lesion) (Figure 5). Three fixtures (Replace, NobelBiocare Zurich, Switzerland) were placed in the posterior maxilla and the denture fitted.

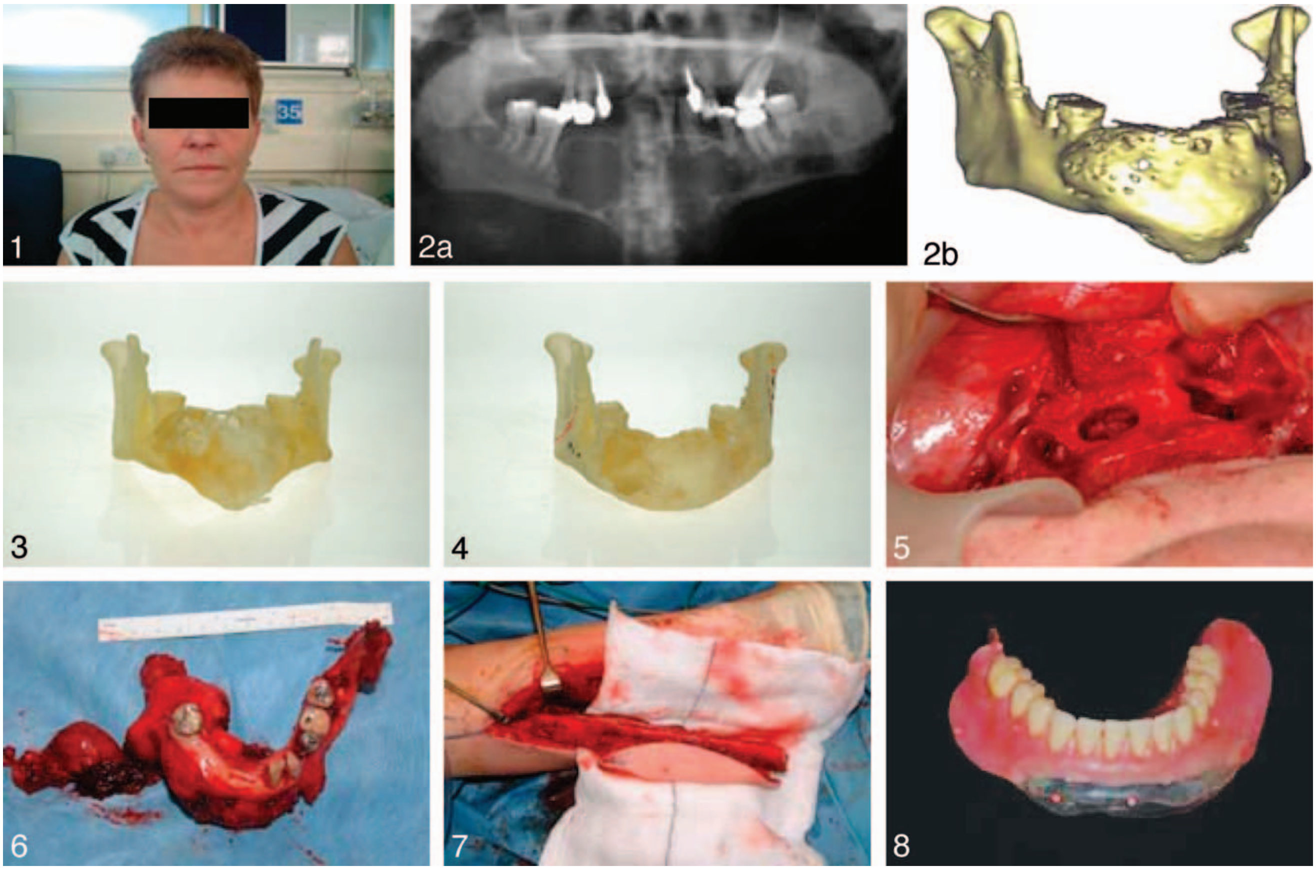
Mandibular surgery took place with resection of a substantial part of the jaw and soft tissues of the floor of the mouth and upper neck (Figure 6). A segmented, fibular microvascular free-flap (Figure 7)[1] was fixed in place on the prebent fixation plate, which was positioned on the mandibular remnants with the help of guides. Intraoral and extraoral healing proceeded uneventfully.

There was a need to deliver the implant placement within a few weeks of the surgery, prior to radiation therapy, because the final histology reported the presence of pleomorphic adenoma with some adverse features such as increased numbers of mitoses within the resected specimen.

Thus, just 4 weeks after surgery, the original tooth set-up arrangement was rearticulated on a new base plate formed on a model made from an impression of the neomandible. Light-cured resin was used to extend this "try-in" in situ; 6 gutta-percha markers were embedded in the surface of the set-up to transform it into a radiolucent radiographic stent (Figure 8). The patient was rehearsed in the use and correct positioning of the stent.

The patient was then scanned with a cone beam computerized tomography (CBCT) scanner (I-Cat, Imaging Sciences, Philadelphia, Pa) with the stent in occlusion with the maxillary denture and with an interdental index in place; the stent was then scanned separately. The resulting DICOM data were then imported into implant planning software for computer-guided surgery[6] (NobelGuide, NobelBiocare, Gothenberg, Sweden) as shown in Figures 9 and 10. Implant placement was planned aiming to provide optimal support for a full arch prosthesis, having abutments positioned in oral mucosa where possible (3 fixtures) and emerging through the skin of the flap where this proved unavoidable.

The software was employed to create a surgical



Figures 1–8. Figure 1. The patient at presentation. **Figure 2.** (a) Panoramic radiograph showing expansive lesion to mandibular body. (b) Three-dimensional rendered computerized tomography (CT) scan of the mandible showing expansive lesion to mandibular body. **Figure 3.** Stereolithographic model of the mandible. **Figure 4.** Altered stereolithographic model of the mandible. **Figure 5.** The anterior maxillary teeth were extracted and the cyst simply enucleated. **Figure 6.** The resected specimen. **Figure 7.** The fibula flap raised and still in situ. **Figure 8.** The resin mandibular try-in extended and marked with gutta-percha markers to create a radiographic stent. The resin addition facilitates anchorage of the drill guide, which will be based upon the geometry of the try-in.

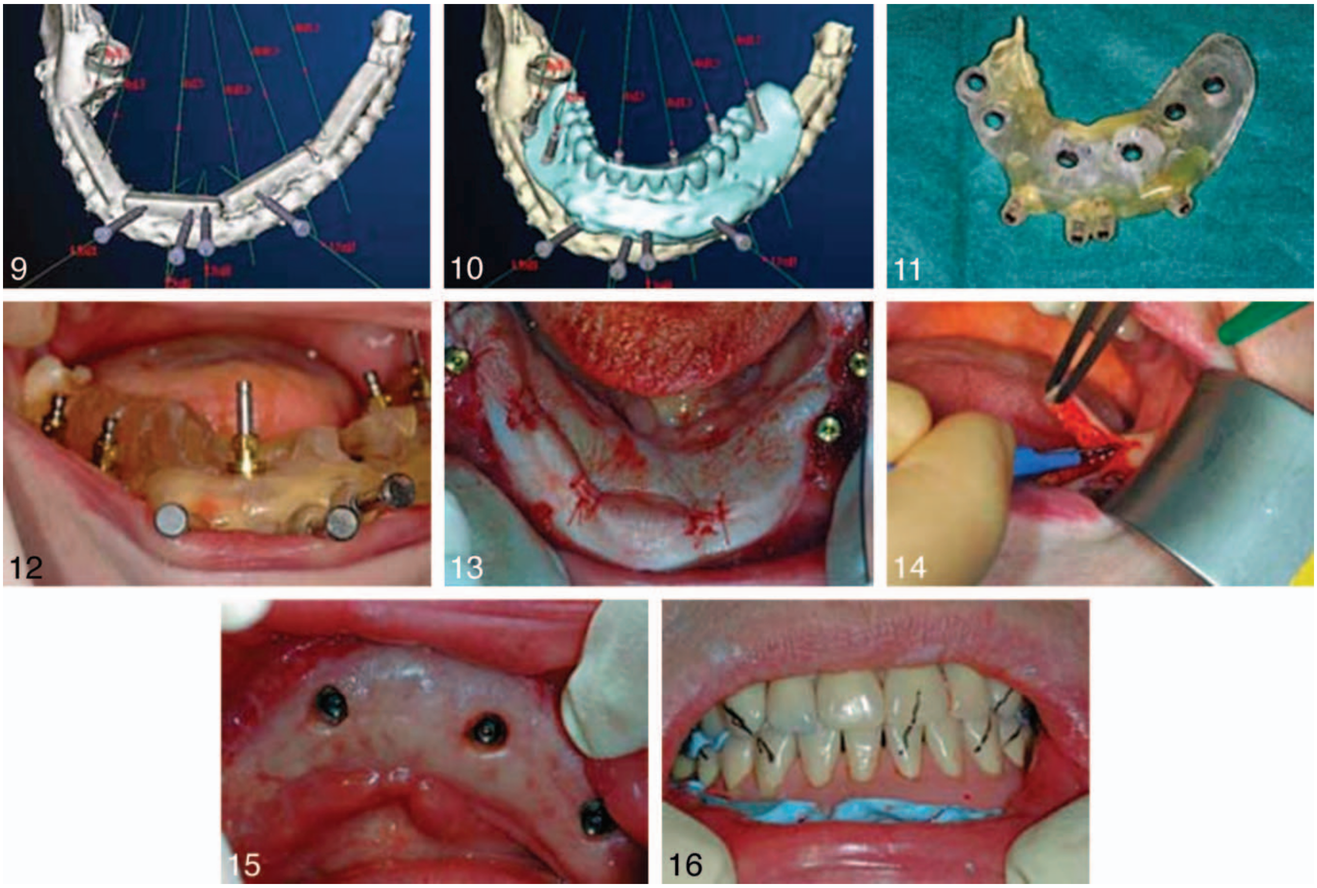
guide (Figure 11). The intaglio surface of this guide was essentially that of the tooth try-in/radiographic stent and, as such, could replace the try-in upon the articulator. Most importantly, this allowed a surgical index to be produced on the articulator at the correct vertical dimension, which could be used to assist in accurately seating the surgical guide, by indexing it to the maxillary prosthesis.

Implant placement proceeded just under 6 weeks post surgery. A standard flapless-guided technique and instrumentation for straight-threaded fixtures (Replace Straight, NobelBiocare) was used (Figure 12). Six fixtures were placed in lengths ranging from 10 to 13 mm, and long healing abutments were placed. Three of these penetrated transmucosally and 3 were buried beneath the bulky skin flap (Figure 13). Further fixtures were conventionally placed in the anterior maxilla.

Two weeks later the flap was debulked to achieve better tissue apposition around the abutments (Figure 14). It was decided that further prosthodontic treatment would be postponed until completion of radiation therapy.

Four weeks after radiation therapy, the 3 buried fixtures were easily identified through the firmer and more closely adapted tissue, and a punch biopsy was used to uncover them (Figure 15). Abutments were connected to all of the fixtures and an impression was taken. The original tooth set-up was cut back and registered intraorally to healing caps affixed to the abutments (Figure 16). The set-up was then transferred to a working model and altered to produce a simple resin fixed partial denture (Figure 17). Similar treatment was carried out in the maxillary arch.

Figure 17 shows how some fixtures emerge buccal to the bridgework. This is inconvenient but



Figures 9–16. Figure 9. The 3D virtual environment showing the reconstructed mandible, radiographic stent, and planned implant positions. **Figure 10.** The 3D virtual environment showing the reconstructed mandible, radiographic stent, and planned implant positions. **Figure 11.** The stereolithographic drill guide. Note that it has been reinforced with a clear resin (shiny material) in view of its relatively fragile configuration. **Figure 12.** Computer-guided surgery in progress. **Figure 13.** Fixtures in place postoperatively. Healing abutments have been buried where skin is overlying so as to facilitate access to the fixture heads; they emerge through oral mucosa. **Figure 14.** The bulky skin and fat overlying the graft is trimmed to thin the tissues. **Figure 15.** Three fixtures/abutments emerge through the thinned-down overlying skin covering the neomandible. **Figure 16.** Intraoral indexing of the lower set-up to the upper denture prior to conversion of the removable prostheses to simple resin bridgework.

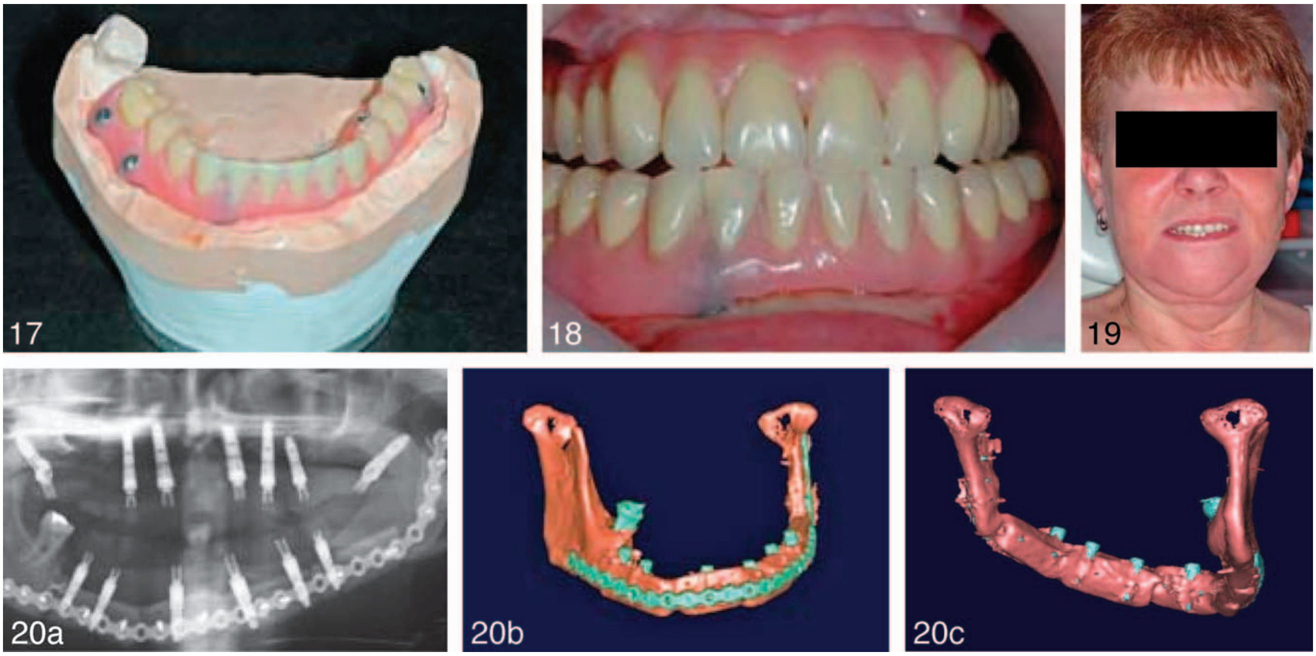
inevitable given the position of the underlying bone graft, which defines the facial profile. The patient is comfortable with the arrangement and is able to keep the bridgework well maintained in both arches. Figures 18 and 19 show both resin-fixed partial dentures in place about 3 months post insertion.

It is now 4 years post radiation therapy and full dental rehabilitation (Figure 20a, b, and c). No implants have been lost and the patient is taking a full, normal diet. No hyperbaric oxygen treatment had been provided at any stage. The patient rated her overall quality of life as "good" on completion of the University of Washington Quality of Life Questionnaire. Specifically, she reported that she had "no pain, but a little stiffness," she remains active and there are few things she cannot do. She can chew and swallow most foods, her taste is unaffected and her speech is excellent.

Discussion

This case illustrates the importance of involving the restorative dental team at an early stage in treatment for patients requiring resective and reconstructive surgery. Most importantly, the planned reconstruction and tooth arrangement was defined prior to surgery and records kept of tooth position and arch form.

The use of the RPAMs (Figures 3 and 4) in order to prebend the fixation plate and plan the surgical approach expedited free flap reconstruction and ensured an accurate and predictable postoperative



Figures 17–20. Figure 17. The prosthesis is indexed to the working model and adapted to form a simple resin bridge. **Figure 18.** Resin bridges in place 3 months post insertion. **Figure 19.** The patient 3 months post insertion of fixed bridgework. **Figure 20.** (a) Postoperative panoramic radiograph showing implants within bony envelope. (b,c) Postoperative 3-dimensional rendered cone-beam computerized tomography scan of the region showing implants within bony envelope. Compare with Figures 9 and 10.

jaw and facial profile and made it possible to appropriately place the implants later on.

Reconstruction of the mandible with free flaps is now commonplace, but the use of removable dentures post reconstruction can be difficult, particularly if adjunctive radiation therapy is employed. Therefore, reconstruction should ideally take place with the provision of dental implants and the position of the grafted bone in relation to future implant placement in mind. The thickness of the overlying skin flap in the oral cavity and the position of fixation plates and screws should be carefully considered. Kramer et al[2] found a 96% success rate in 51 implants loaded after 3 months of submerged healing. Importantly, in their series, one of their fixtures failed when placed at the interface between graft and native mandible. Two fixtures were left uncovered because of inappropriate soft tissue coverage.

The use of a computer-guided approach to implant placement hugely facilitates implant surgery in 3 principal ways. Firstly, implant positions can be planned precisely in relation to the available bone and the planned prosthetic tooth position. Secondly, the implants can be placed using a flapless, minimally invasive technique through the reconstructive skin flap in the mouth. This was particularly important given the limited timeframe available for treatment between healing of the flap and the commencement of radiation therapy and the unfamiliar anatomic environment. Schepers et al[13] showed a 97% success rate for implants placed at the time of resective surgery (21 patients, 61 implants) with postoperative radiation therapy. The minimally invasive approach and the timing of implant surgery used in this case might possibly be expected to favor osseointegration. Thirdly, implant positioning in this highly complex environment can be planned to avoid the vascular pedicle to the reconstructive bone and skin (damage to this will destroy the free flap reconstruction completely) and the numerous fixation screws and the bone fixation plate.

It was imperative that the relationship between the radiographic stent and the jaw would be the same as the relationship between the drill guide and the jaw so that the same planned relationship would be accurately transferred from virtual plan to reality. Figure 20b and c shows a postoperative 3D rendered CBCT scan of the region; the system appeared to function with great precision, despite the fact that the reconstructed ridge was flat and the overlying skin flabby in this rather challenging situation. This highlighted the importance of having a stable opposing dentition/prosthesis and a well-fitting occlusal index at the correct vertical dimension to stabilise the guide.

Microvascular free flaps act as "vascular donors" to the recipient bed as long as the single artery and vein that supply blood flow remain intact. This is distinct from grafts that must receive a "random" blood capillary ingrowth from the recipient bed within a few days if they are to survive. Therefore, free flaps are more resistant to the adverse vascular effects of radiation therapy and may not require supportive hyperbaric oxygen therapy to improve wound healing and implant survival. However, greater care must be taken to preserve these vital blood vessels, the muscular attachments to the periosteum and the periosteum itself must not be stripped from the bone if the vascular benefits of the free flap are not to be lost. Also, there are limits to the number of osteotomies possible with microvascular bone flaps compared with bone grafts due to prejudice to the corticocancellous blood supply distal to the osteotomy site. In these situations, the distal bone relies on blood vessels in the muscle and periosteal attachments, so greater care must be taken not to tear these off the bone. All of these factors make implant placement more difficult in microvascular free flaps because of the thickness of the overlying soft tissues and the limits on bone contouring. These disadvantages are outweighed by the ability to safely and reliably reconstruct huge bony and soft tissue defects and then place implants with high success rates despite adjunctive radiation therapy.

Summary

A patient with extensive mandibular infiltration and destruction by a recurrent sublingual gland salivary pleomorphic adenoma was treated with three-quarter mandibular resection, and fibula osteocutaneous free flap reconstruction was restored with bridgework supported by osseointegrated implants placed using a computer-guided technique. Prosthodontic aspects of treatment were planned alongside surgery to permit a high degree of control over the appearance and function of the definitive reconstruction.

Abbreviations

CBCT: cone beam computerized tomography
CT: computerized tomography
RPAM: rapid prototype anatomic model

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