Achieving predictable outcomes of mandibular reconstruction with virtual treatment planning

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One of the main goals of reconstruction of mandibular defects is to restore mandibular continuity and morphology to allow functional rehabilitation with osseo-integrated dental implants. This is a challenge if significant distortion of the normal anatomy has occurred due to the aggressive nature and extensive growth of the various pathologies involving the mandible. Various options are available for mandibular reconstruction, but autologous grafts remain the gold standard in various forms.[1, 2] Whilst free flap reconstruction allows for immediate reconstruction, the particulate cortico-cancellous bone (PCCB) graft allows for a far more accurate restitution of mandibular morphology and facial aesthetics (with decreased cost and morbidity), as it permits for more accurate dental rehabilitation.[3-9] A challenge for reconstructive surgeons has been reconstituting the mandibular arch as this has implications for facial form and dental arch replication. The use of virtual treatment planning improves the predictability of reconstructive goals. A protocol refined over several years, exploiting virtual treatment planning when appropriate, has optimized treatment outcomes and is reviewed by presenting the treatment sequence for a typical case.

Following clinical examination, planning for resection and intermediate reconstruction requires a computed tomography (CT) scan. The slice data is saved in Digital Imaging Communication in Medicine (DICOM) format and imported into Mimics Software (Materialise, Leuven, Belgium). The CT scan is then viewable as a 3D image to allow for virtual resection, which gives detailed information regarding the extent of the lesion to plan the resection and ensure pathology free margins (Figure 1). The three dimensional images are imported into 3-Matic software (Materialise,

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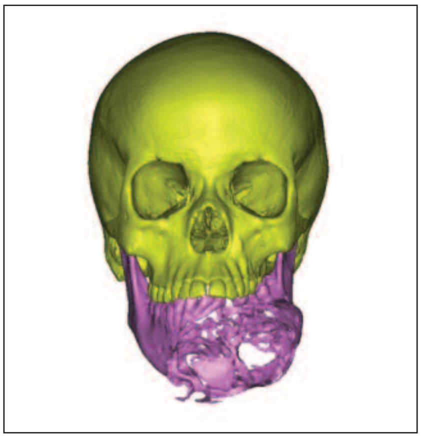


Figure 1: Reformatted 3D CT Scan of a mandibular tumour.

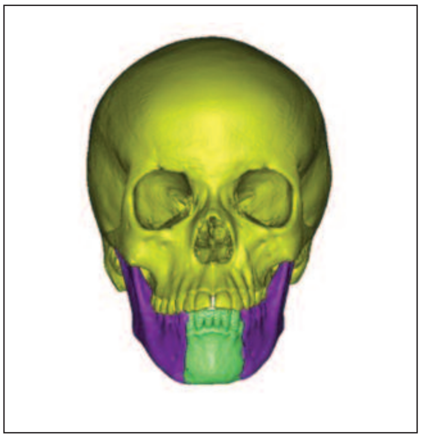
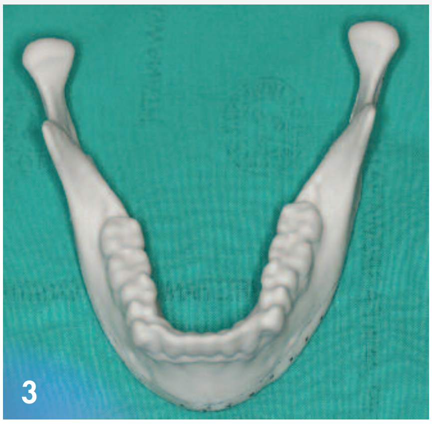


Figure 2: Undistorted virtual mandible.



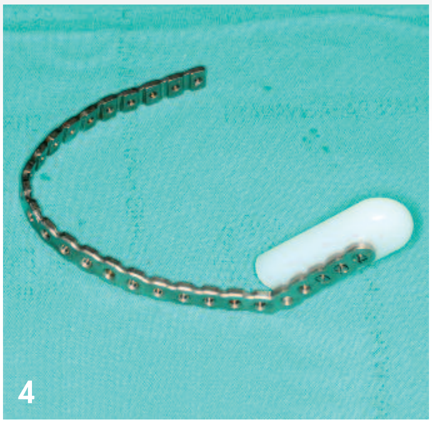


Figure 3: 3D printed model.
Figure 4: Patient matched titanium reconstruction plate with condyle/ramus spacer.
Figure 5: Mandibular resection specimen.

Belgium) to create a virtual mandible unaffected by distortion (Figure 2). A model of the ideal mandible is prepared with zp 131 powder silica, plaster composite on a Z Corp 510 3d inkjet printer (Z-Corp, Burlington, Massachusetts) (Figure 3). [10]

Using the model, a 2.4mm titanium reconstruction plate is adapted directly on the printed model (Figure 4). The tumor is resected (Figure 5) and with the aid of measurements and markings obtained from the 3D model and virtual planning, the reconstruction plate is secured to the extant mandible. Once the plate is secured, a silicon spacer is secured to the plate with wires. The spacer sculpts the healing of the soft tissues to form a recipient bed into which the bone graft will be placed 8 weeks later (Figure 6a & b). After securing the spacer, the inter-maxillary fixation is released to ensure the correct aesthetic positioning of the plate. Thereafter, the soft tissues are closed in layers, starting with the appropriate reattachment of the suprahyoid and supraglottic musculature. The patient is then placed into inter-maxillary fixation for the post-operative period of 6 weeks. Post-operatively the patient is monitored in the Intensive Care Unit for the initial 24 hours. All medication is administered intravenously and all feeding is via nasogastric tube for the first 7 days post-surgery.

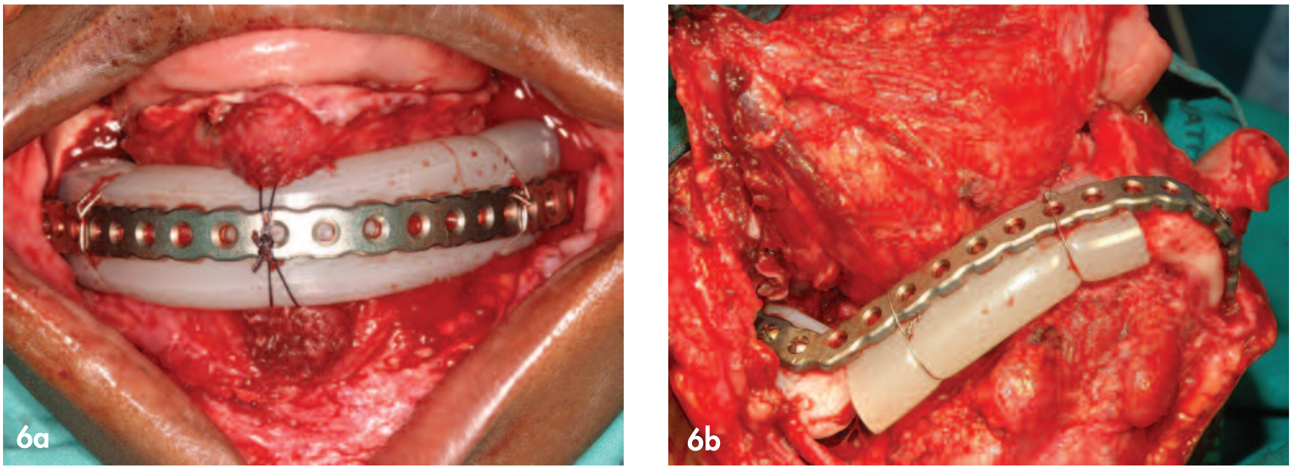


Figure 6: (a) Spacer secured via intraoral approach, (b) via extraoral approach to titanium reconstruction plate.

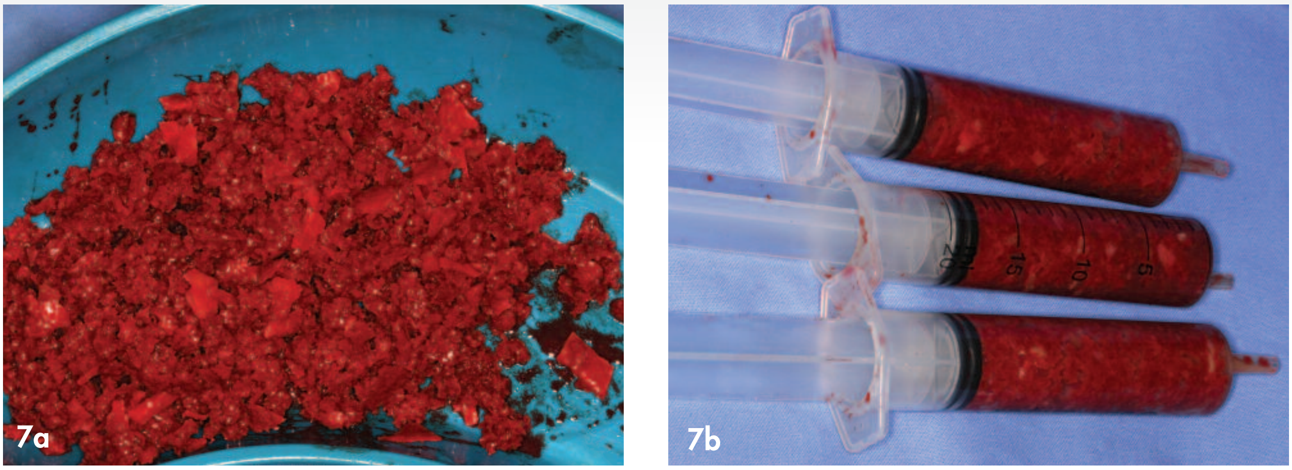


Figure 7: (a) Particulated cortico-cancellous bone graft, (b) compressed into syringes.

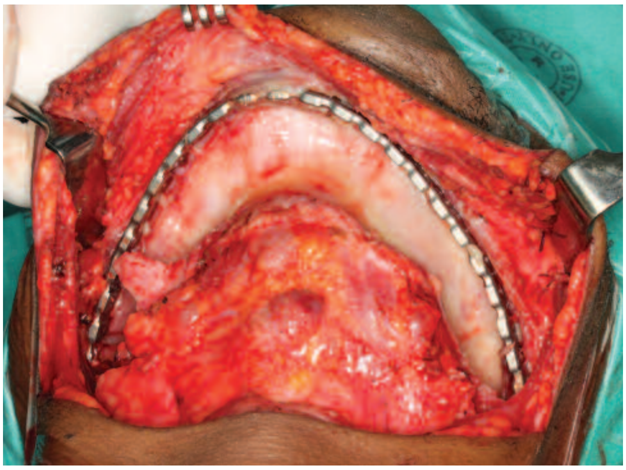


Figure 8: Recipient soft tissue bed after spacer removal.

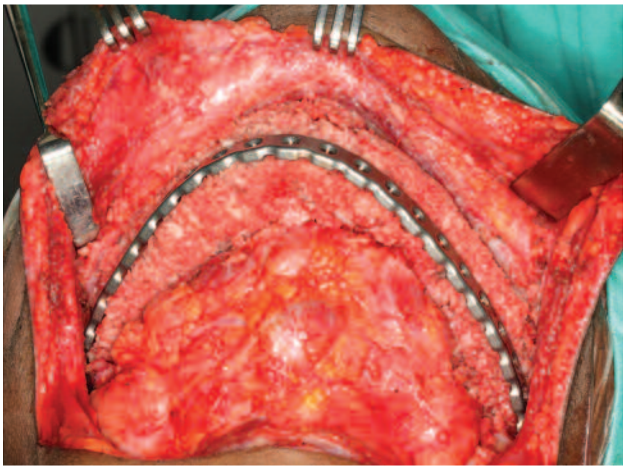


Figure 9: Compressed bone graft packed into recipient soft tissue bed.

After eight weeks, definitive reconstruction is effected with a posterior iliac crest graft (bilateral or unilateral depending on defect size), as a large volume of cortico-cancellous bone is required to adequately reconstruct the mandible (Figure 7a). The bone is milled and packed into 20ml syringes and maximally compressed to ensure a compact bone graft (Figure 7b). The spacer is exposed via an extraoral approach. If healing has been uneventful, a smooth recipient bed (Figure 8) will have formed for the placement of the particulate bone graft (Figure 9). The malleable nature of the PCCB graft and its implantation into a recipient bed sculpted by a spacer allows duplication of mandibular arch form (Figure 10).[9] Once grafting is complete, layered tension-free closure of the soft tissues is carried out around the plate and grafted bone. The patient is then placed into inter-maxillary fixation to allow for stability of the graft and soft tissues to heal uneventfully.

Post-operative care is the same as the first surgery, i.e. patient is monitored in ICU for the initial 24 hours, followed by another 6 days in hospital with continued monitoring ensuring operative sites healing well. Patients are reviewed weekly until inter-maxillary fixation released at 6 weeks.

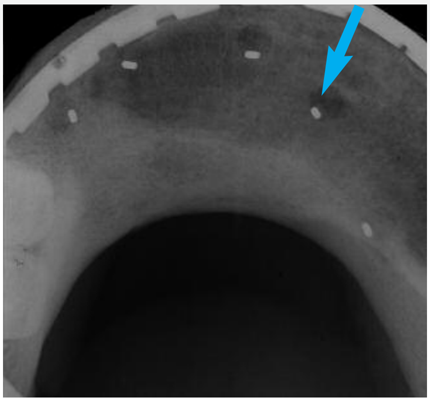
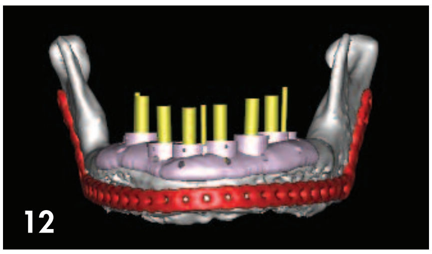


Figure 10: Diagnostic wax up indicators (arrows) seen on occlusal X-ray for implant planning. Good restitution of arch form and trabecular pattern.

Figure 11: Panoramic radiograph 6 months post grafting showing loss of mandible/graft interface, restitution of alveolar height and trabecular morphology.

Six months later, planning is initiated for the dental rehabilitation of the grafted patients. Graft maturation is confirmed with panoramic radiography, once the graft/mandible interface is not visible and normal trabecular pattern has been established (Figure 10 & 11). Planning for implant placement follows the standard approach for guided implant placement. A diagnostic wax up is prepared as an aid to scan template manufacture. The patient has a CT scan of the trial prosthesis in position to facilitate appropriate virtual implant placement. Treatment planning can be done with one of several proprietary software packages (Figure 12). Based on the treatment planning a surgical guide is manufactured (Figure 13a) and used to place the implants (Figure 13b). Impressions are taken in theatre for the construction of a sulcus conformer. Healing abutments are then placed and the mucoperiosteum sutured closed. Three months post placement a sulcoplasty is performed and sulcus molding is aided by a conformer (Figure 14a & b) secured to the implants. Once secondary mucosalization is complete definitive prosthesis is manufactured (Figure 15a, b & 16).

The impact of loss of mandibular continuity on a patient's quality of life is substantial. Resolving the multiple problems associated with the loss of this complex organ is essential to return patients to pre-morbid function and appearance. The protocol reviewed here has been refined over several years and has been used to treat over 60 patients. The addition of digital technology coupled with a sound understanding of the biology of bone grafting ensure repeatable and predictable outcomes for patients with devastating surgical injuries.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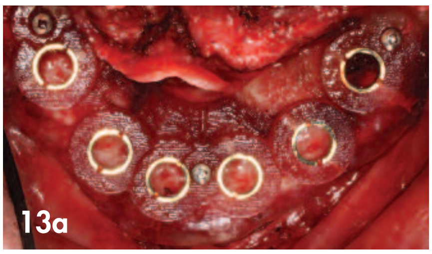
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Figure 12: Virtual treatment planning of implant positioning and surgical guide.
Figure 13: (a) Surgical guide in position, (b) placement of implants in grafted mandible. Bone graft is well consolidated with a prominent cortical layer.

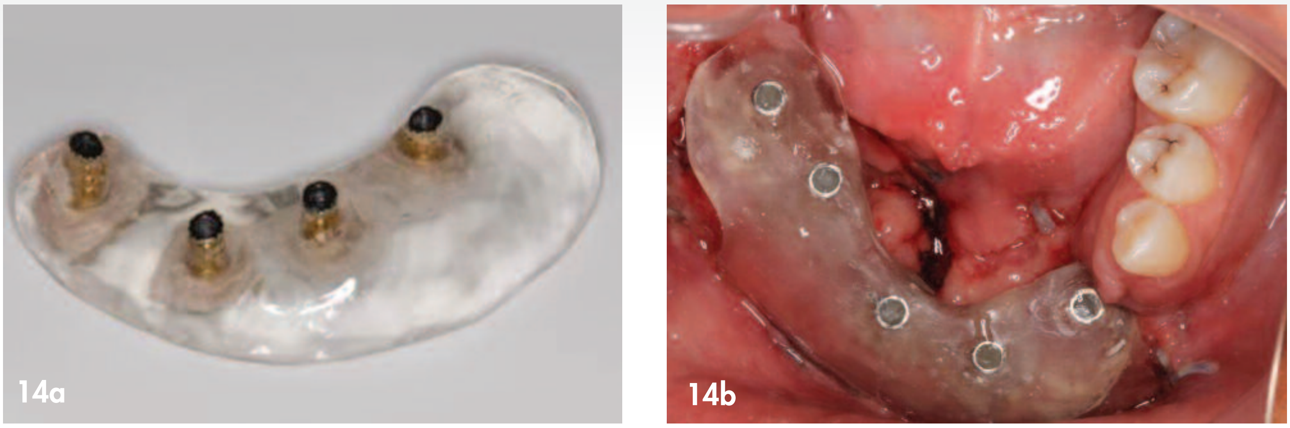

Figure 14: Sulcus conformer in situ following sulcoplasty surgery.

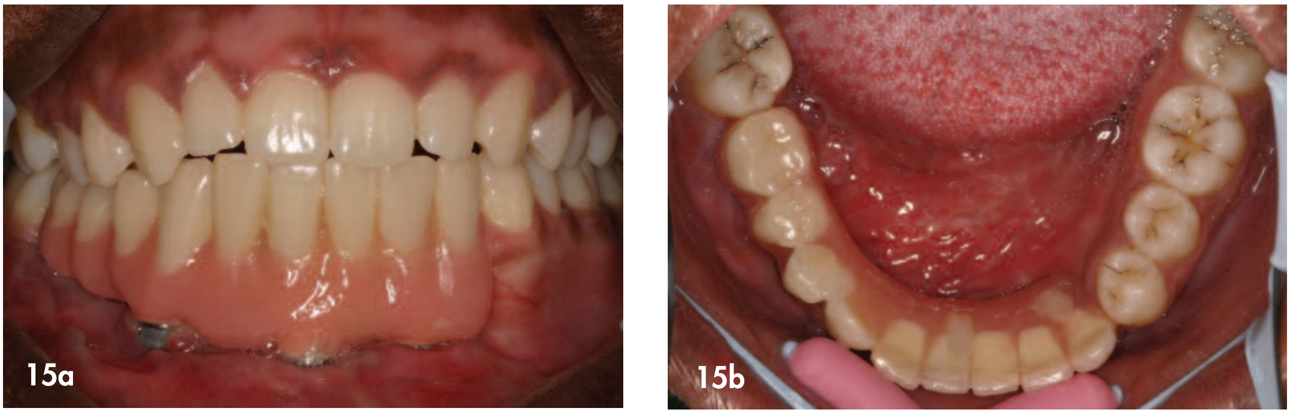

Figure 15: (a) Frontal and (b) occlusal view of final prosthesis in situ. Prosthesis height fulfills the criteria for good implant/crown ratio. Position of access holes confirm ideal implant position.

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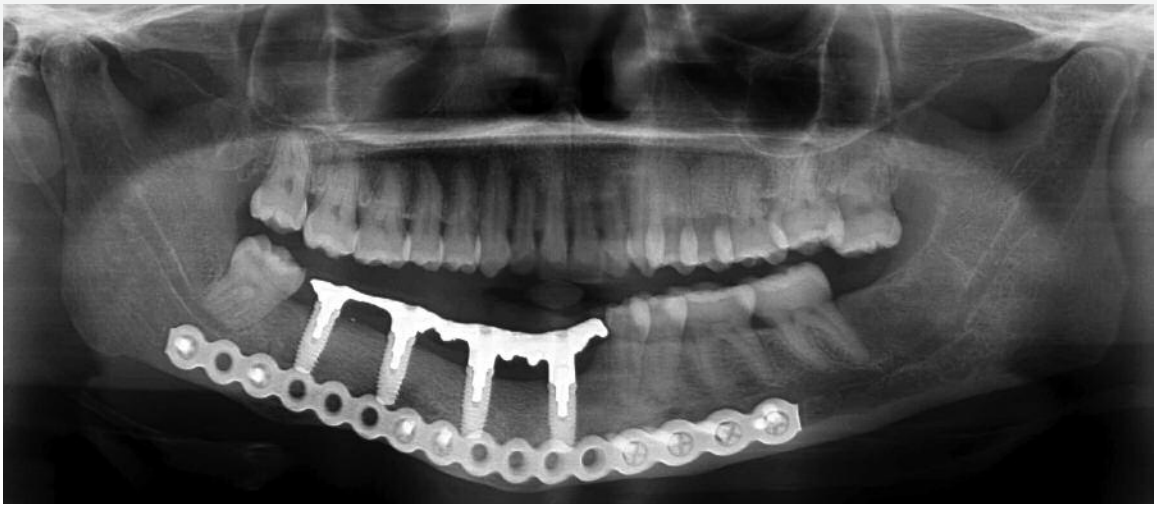

Figure 16: Panoramic radiograph of final prosthesis in situ.

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