3D Printed Mandibular reconstruction - Caribbean Case report

C Naraynsingh[1], R Ramoutar[2], Rodolfo Fundora[2], Solaiman Juman[2]

[1]Department of Oral and Maxillofacial Surgery, School of Dentistry, Eric Williams Medical Sciences Complex, University of the West Indies

[2]Department of Otolaryngology, Clinical Surgical Sciences, Eric Williams Medical Sciences Complex, University of the West Indies

Corresponding Author

Candy Naraynsingh
Department of Oral and Maxillofacial Surgery
School of Dentistry
Eric Williams Medical Sciences Complex
University of the West Indies
Email: candy.naraynsingh@sta.uwi.edu

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ABSTRACT

Mandibular reconstruction following resection of tumors can be challenging for surgeons globally and in the Caribbean. This case highlights the use of a 3D printed Patient Specific Implant for mandibular reconstruction following resection for Ameloblastoma. This has not been previously reported in the regional literature and includes a brief discussion of the challenges of mandibular reconstruction and the impact of Patient Specific Implants.

Introduction

Treatment options for benign jaw tumors include enucleation and curettage or resection. Once resection is done, reconstruction of the mandible presents many challenges to surgeons across the globe as well as in the Caribbean. Ideally tumor ablation should be followed by orofacial reconstruction to achieve the optimum functional and cosmetic outcome for the patient.[1]

Options for reconstruction may include primary closure, non-vascularized or vascularized local, regional or distant flaps. These vascularized flaps may be soft tissue or osteocutaneous flaps. Prosthetic materials may also be used.

The following presents a case of mandibular reconstruction using solely a patient specific titanium prosthesis which was a 3D printed. This has not been previously reported in the regional literature and includes a brief discussion of mandibular reconstruction and the role of patient specific implants.

Case report

A 48-year-old Afro-Trinidadian female with no known medical problems presented to the Oral and Maxillofacial Department with intermittent pain and swelling in the anterior mandible for the past four months. The progressive increase in the size of the swelling caused her previously well-fitting dentures to become unusable. There was no associated sensory changes or loose teeth.

She had been treated 15 years ago for a similar swelling in the anterior mandible. At that time the swelling was

one centimeter (1 cm) in size located at the mental prominence. The lesion was excised in its entirety and histopathology was noted as an infected dental cyst.

Six years later she presented again with a similar swelling. The patient had enucleation of the lesion and extraction of the mandibular canines. She was outfitted with dentures to compensate for the extracted teeth. There was no pathological report available at this time.

On her most recent presentation an Orthopantomogram taken showed a radiolucent lesion in the anterior mandible. Following incisional biopsy, a histological diagnosis of follicular ameloblastoma, of the acanthomatous variant was reported. As the patient had experienced three recurrences with conservative treatment, the decision was made to perform resection and interim reconstruction with a plan for formal reconstruction at a later date provided tumor margins were clear. The patient was counselled on the diagnosis and options for treatment and underwent an intra-oral resection of the anterior mandible. Reconstruction was done using a standard 2.4-millimetre titanium plate in the lower anterior region.

She had an uncomplicated recovery and was followed up in the outpatient clinic.

Two years after initial surgery the intraoral wound dehisced and exposed the plate intraorally. There was no evidence of tumor recurrence. Options for reconstruction at this point included a non-vascularized or vascularized graft, both of which she refused. In order to maximize her aesthetics and function, a patient specific 3d printed plate (KLS Martin IPS ©) was planned for reconstruction without bone grafting. The surgical plan involved a work flow involving three crucial steps.

Step 1

The CT scan was performed using KLS Martin IPS Implants © Scan protocol which involved accurate patient positioning and included scan spacing of 0.75 – 1.25 mm and slice thickness of 0.75 -1.25 mm.

Step 2

Using the IPS Gate software © the CT was sent as a DICOM file which allowed virtual surgical planning using CAD technology in consultation with the surgeon and verification and approval of the final design of the implant (Figure 1a).

The plan also allowed for preselected screw lengths to be used in order to achieve bicortical fixation at the desired angulation in order to achieve maximum fixation and stability. This is a significant advantage of 3d implants (Figure 1b).

Step 3

This was followed by production of a 3D stereolithic model and fabrication of the implant using an additive manufacturing process. This process involved selective laser melting of titanium molecules allowing for the production of a complex 3d titanium implant (Figure 1c). The mandibular implant was placed via an extraoral approach using a visor flap (Figure 1d).

The musculature overlying the defect was sutured through the screw holes anteriorly. The use of these holes to reposition the mentalis improved the cosmesis of the lip. She required a covering tracheostomy for this procedure and was successfully decannulated three (3) days post-operatively.

The patient had an uncomplicated procedure and recovery. At the initial resection, a shelf of alveolar crestal bone was retained to accommodate retention of a prosthesis. This was utilized in the design of an acrylic denture which was fabricated and fitted to improve aesthetics and restore the occlusion (Figure 2 a, b, c). The acrylic denture provided good support for the soft tissues of the lip and improved the aesthetics and occlusion. There was no tissue necrosis or plate exposure at three years post operatively.

Discussion

Ameloblastomas are mostly benign tumors that are second only to keratocystic odontogenic tumors, as the most common odontogenic tumor of the jaw.

Surgical management is the standard of treatment. Two surgical options exist in the management of ameloblastomas - the radical approach and the conservative approach. The conservative approach calls for enucleation and curettage while the radical approach refers to either a segmental or a marginal resection.

Enucleation and curettage are minimally invasive procedures with few potential complications and little associated morbidity. Research has shown however that simple enucleation can produce recurrence rates of sixty

Figure 1: a. Preplanned placement of screw holes and preselected lengths b. Computer Assisted Design c. 3D Printed model d. Intraoperative placement of a patient specific mandibular implant (KLS MARTIN GROUP)

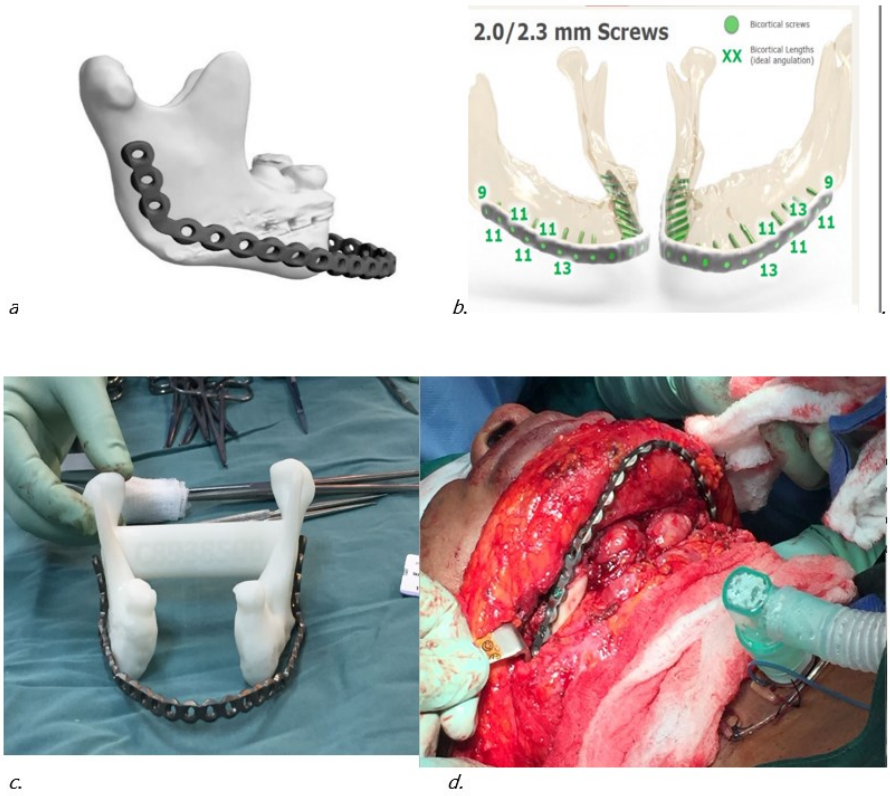

Figure 2: a. Healthy soft tissue defect b, c removable dental prosthesis in situ d, e. Pre- and Post-operative facial profile showing improved aesthetics with patient specific implant and a dental prosthesis in place

to ninety percent (60 – 90%) and it is for that reason that it is not applied to the management of multi-cystic ameloblastomas. The patient had histological evidence of a solid or multi-cystic ameloblastoma and was thus planned for a radical procedure with reconstruction.

Radical surgery involves a segmental or a marginal mandibulectomy. The index patient's lesion was located in the anterior mandible. An anterior segmental mandibulectomy was initially performed with a 1.5 cm resection margin. Ameloblastoma cells have been identified in tissue located up to eight millimeters (8 mm) away from the clinical and radiological margins. Therefore, the generally accepted resection margins are defined as one to one and a half centimeters (1 -1.5 cm) away from the bony margin.[2]

The resultant discontinuity produced in the mandible affects speech, swallowing, aesthetics and airway stability.[3] This is especially difficult in the anterior mandible where a loss of continuity of bone and submandibular tissue which affects facial height and chin projection. Restoring aesthetics in this location can be achieved by taking these into account when planning for reconstruction.[3]

Reconstructed patients have shown a higher quality of life in terms of speech, mastication and cosmetic appearance, when compared to non-reconstructed patients.[1]

The timing of reconstruction, whether immediate or delayed is controversial. Immediate reconstruction offers psychological benefits and there decreased surgical difficulty as there is no tissue contraction due to scarring.[4] Parmar et al advocate for delayed reconstruction on the basis that a staged procedure allows for histological confirmation of negative margins, and thus reconstruction is done in an oncologically clear field.[5]

The method of reconstruction is another topic of debate. Several options for mandibular reconstruction are available. Autogenous osteocutaneous free flaps and soft tissue pedicled flaps are the mainstay for reconstruction with or without reconstruction plates. Alloplastic materials have also been used.

The vascularized osteocutaneous free flap is noted as the present standard for reconstruction of the mandible. It was shown by Cordeiro and Kuriloff to have a high success rate, despite the noted advantage in that it is harvested and sculpted easily and has good functional outcomes.[6,7] This flap provides good bone stock and is well vascularized. It has a bicortical structure that is suitable for dental implants. When compared to other free flaps there is less donor site morbidity. However, it is technical challenging, time consuming, requires microvascular expertise and two teams of surgeons.[3]

Other free flaps that can be used include the iliac crest free flap and anterolateral thigh flap for soft tissue or the radial forearm flap.[3] Soft tissue pedicled flaps with or without reconstruction plates and non-vascularized bone grafts for reconstruction of non-vascularized small bone defects < 3cm are other options.[3]

Alloplastic materials include prefabricated reconstruction plates, PMMA acrylics and bone substitutes such as hydroxyapatite bone blocks. Autologous bone grafts are subject to resorption and both donor and recipient site complications. Acrylics may be immunologically rejected and hydroxyapatite may be difficult to adapt.[8] Alloplastic reconstruction using plates and screws have been shown to have possible complications of loosening of the screws and plates with subsequent migration of the implants.[9] This was evident in the index case who presented two years after her initial reconstruction with anterior and superior malposition of the implant. The decision was taken to provide the patient with a Patient specific implant to improve cosmesis.

Patient specific technology has been introduced in the last decade. The advantages of Patient Specific Implants (PSI'S) include a better fitting implant, decreased surgical time, rigidity and biocompatibility, accuracy of preoperative planning and decreased morbidity due to no donor site complications.[10] The costs of this technology are offset by shorter hospital stays and faster rehabilitation.

One other advantage of PSI's is the ability to be creative with complex designs that can accommodate tissue engineered materials such as collagen-based scaffolds, particulate cellular bone and marrow and bone morphogenic proteins.[3] Technological advances are allowing the ability to create specific designs to maximize the biomechanical advantages. Using additive manufacturing. screw hole positions can be tailored to allow for designated suture anchor holes. Finite element analysis (FEA), can be used in design planning to accurately predict the exact site of plate fracture and

incorporate for in the design.[10]

Porosity can be planned in the design to optimize the weight of the implant. The stereolithic models can also be used to simulate procedures, teach students and advise patients.[10]

The ability to use implant only reconstruction as alternative to free flaps has been supported by Cho and Kim (2015), Reitmeier et al (2016) in animal studies and Markwardt et al (2014).[10]

The limitations of PSI's include the need for more intensive preoperative planning and the lack of randomized controlled trials on their use.[10] Utilizing a PSI also means that the intraoperative plan cannot be changed. There is also no accommodation for tumor growth which will alter resection margins, technical surgical errors and legislature in some countries.[10]

Preoperative planning includes imaging where CT or MRI scans are required to create a 3D model which is manipulated according to surgeon and engineer specifications to create an implant that matches the patient. The implants are then made by a process called additive manufacturing or 3D printing, using various methods and materials such as plastics, bio-ceramics or metals. Despite the increased preoperative planning required, turnaround times are becoming faster due to more easily accessible commercially available software.

A systematic review of the evidence for PSIs by Goodson et al (2019) revealed that the literature provided mostly case reports on PSIs as it is relatively new and rapidly evolving. There were few prospective clinical studies comparing PSIs with conventional techniques with no randomized controlled studies. Interestingly the authors found PSIS were used for mandibles predominantly.[10]

Despite the lack of randomized controlled studies and limitations there are several advantages of PSI's. Their use may have an important evolving role to play in the future in mandibular reconstruction.

Conclusion

Ameloblastomas of the mandible can produce lesions that cause severe cosmetic and functional deformity to the afflicted patient. In addition, reconstructive efforts to repair the mandibular defects produced by excision, require specialized methods and materials. An emerging technology in patient care is the use of patient specific or 3D printed implants that allows for greater cosmetic and functional application, shorter operating time and faster recovery rates.

Although vascularized grafts remain the gold standard of reconstruction, the advantages of PSI's and their future standalone role in mandibular reconstruction requires further research. This case highlights an alternative that is attainable in our setting with good esthetic and functional results three years post operatively.

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