Immediate Teeth in Fibulas: Expanded Clinical Applications and Surgical Technique

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Purpose: The placement of immediate implants and teeth during jaw reconstruction using a fibula free flap has increased in recent years. Modifications of traditional fibula reconstructive techniques are needed to maximize success. This technique has not been described in patients requiring simultaneous soft tissue reconstruction. Our patient cohort includes cases with malignant pathology and those requiring skin paddles. With digital workflows and point-of-care 3D printing, surgery is no longer delayed weeks for prosthesis fabrication. The purpose of this case series is to demonstrate a single institution's experience with expanded clinical applications and surgical techniques that enable predictable outcomes for immediate teeth in fibula flaps.

Materials and Methods: Ninety-five implants were placed in 22 patients undergoing fibula reconstruction of the jaw with immediate implants and an immediate dental prosthesis. Skin paddles were used in 10 patients while 12 patients had native mucosa. Six patients were treated for malignancies and underwent postoperative radiation. Implant success and complications were compared between implants with skin paddles and implants with native mucosa.

Results: Of 95 implants, 92 implants integrated for a 97% integration rate. All 13 radiated implants in 4 patients integrated. All 36 implants adjacent to skin paddles in 10 patients integrated. Seven implants were lost in a delayed fashion 9 to 15 months postoperatively resulting in a 93% overall implant success rate. Of the 22 patients, diagnoses were benign pathology for 11 patients, malignant pathology for 6 patients, gunshot wounds for 3 patients, and osteoradionecrosis for 2 patients.

Conclusion: Immediate placement of dental prostheses on immediate implants during fibula reconstruction of the jaws can be performed with a high rate of predictability. This technique can be expanded to select patients needing skin paddles. Modifications of traditional fibula reconstructive techniques are helpful to minimize soft tissue and prosthetic challenges.

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Interest in comprehensive jaw reconstruction has led to the development of new techniques to provide immediate implants and teeth at the same time as vascularized bone reconstruction.[1-4] While immediate implants in vascularized fibulas have been placed for many years, these implants are usually not immediately restored.[5,6] Delayed early provisionalization has been described but requires a period of days or weeks without teeth.[7]

Immediate placement of a dental prosthesis at the time of fibula reconstruction requires special consideration for fibula positioning and peri-implant soft tissue management. Specific modifications of fibula harvest and inset can facilitate healthy peri-implant soft tissue. We will introduce expanded applications and our surgical techniques, including the use of simultaneous skin paddles and the floating prosthesis for accurately attaching the dental prosthesis to implants while the fibula remains perfused on the leg.

Materials and Methods

A chart review was performed to identify patients who underwent fibula reconstruction of the mandible or maxilla with immediate implants and an immediate dental prosthesis. Inclusion criteria required patients to be followed for a minimum of 3 months so implant integration could be verified. Twenty-two patients met inclusion criteria with a total of 95 implants. Implant integration was verified by torque testing implants to 35 Ncm. Of the 22 patients, 10 had skin paddles adjacent to the implants and 4 patients underwent postoperative radiation therapy. Implant integration rates and complications are described, and comparisons are made between implants with skin paddles and implants with native mucosa. The institutional review board of our institution exempts retrospective medical record review with no patient identification.

VIRTUAL SURGICAL PLANNING

When creating a virtual surgical plan for fibula reconstruction, the surgeon must decide how to orient the fibula. The authors prefer to position the fibula where the buccal plate is formed by the lateral surface of the fibula. This is a relatively flat surface where the reconstruction plate is readily adapted far from the pedicle. Minimal muscle usually remains on the fibula in this region which allows straightforward adaptation of the plate. For mandible reconstruction, the medial surface of the fibula containing the pedicle is positioned lingually and therefore protected. For maxillary reconstruction, the pedicle is placed palatally, but the surgeon must plan for a pathway through the soft tissue to drape the pedicle. Remaining maxillary alveolar bone posterior to the fibula may need to be resected to create this pathway. The anterior surface of the fibula is oriented towards the occlusal surface where implants will emerge. One advantage of having implants emerge from the anterior surface of the fibula is that a skin paddle can be placed on the buccal to create a vestibule (Fig 1A, B). Since this skin paddle is rotated from an inferior/buccal position, the resulting slight tension can allow for the creation of a true buccal vestibule.

The fibula has a somewhat triangular shape in cross-section which has implications for proper implant placement. To allow the implant platform to be completely surrounded by bone, deeper placement is often needed. Choosing more narrow implants will minimize the magnitude of this deeper placement. The authors commonly use implants with a 3.75 mm diameter (Fig 2). Care must be taken when placing narrow implants in very dense bone. High

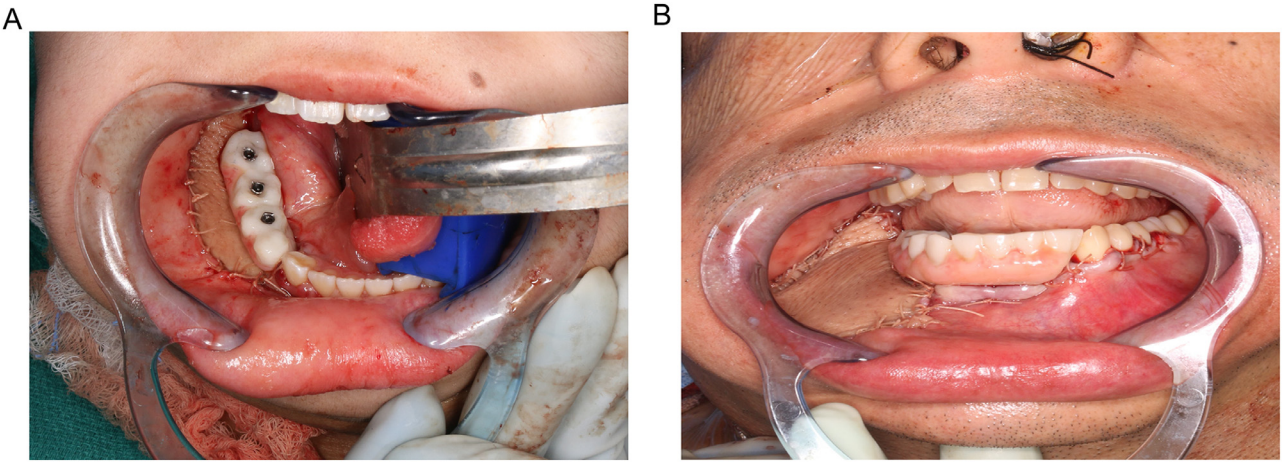

FIGURE 1. (A) Creation of the buccal vestibule with a small skin paddle. (B) A larger skin paddle is necessary for extensive soft tissue defects.

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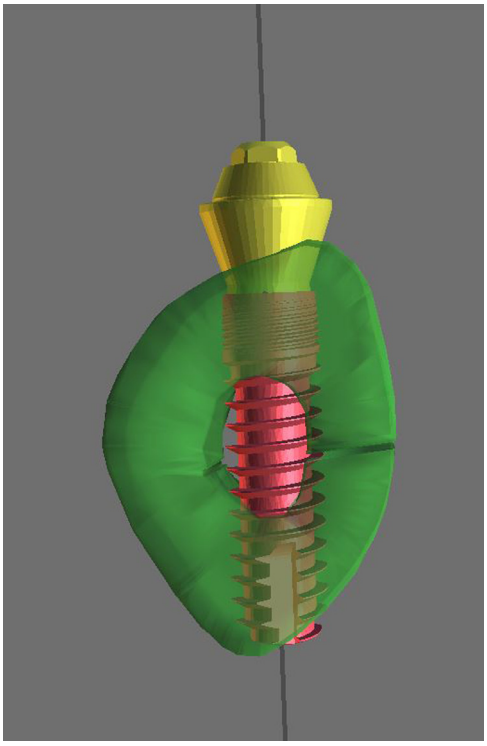

FIGURE 2. Virtual plan of 3.75 × 13mm implant (red) with a multi-unit abutment (yellow) in the fibula (green). Note the subcrestal position of the implant despite the sloping occlusal surface.

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torque values are often encountered which may lead to implant fracture with narrow implants. Implant osteotomies are drilled in a bicortical fashion through the fibula to allow deepening of the implant as needed. The authors commonly place Nobel Parallel CC implants (Nobel Biocare, Zurich, Switzerland).

With the introduction of milled plates, options exist to design plate shape and screw positions to minimize implant complications. Placement of the plate as inferior as possible on the fibula (for the mandible) keeps it distant from the implant site. This lowers the risk of exposing the plate to bacterial colonization if later soft tissue procedures such as vestibuloplasty are performed. Two screws are needed for each fibula segment to prevent rotation. For lateral mandible defects, these can often be placed posteriorly behind the region of implants. It is wise to have multiple screw holes in the plate for fibula segments although only 2 are required (Fig 3).

For large anterior defects resulting in the loss of all teeth, it can be difficult to establish the correct vertical dimension of occlusion (VDO) when attaching the dental prosthesis to implants. Most full arch dental restorations only extend to the first molars. If a full arch prosthesis is planned, second molars should be retained until the end of surgery if oncologically

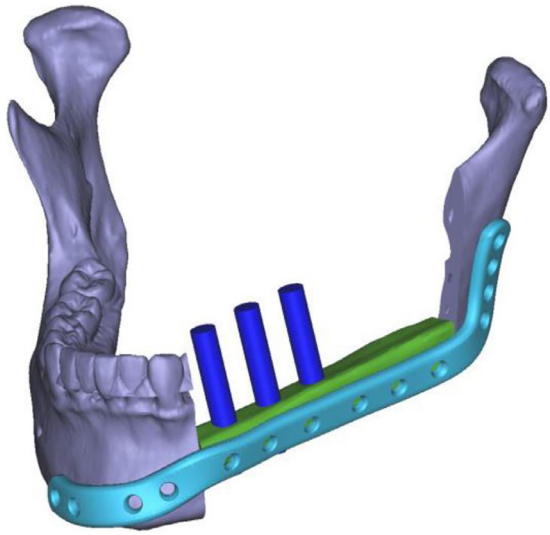

FIGURE 3. Multiple screw holes on the patient specific plate are available to fixate the fibula. Although only 2 holes are needed per fibula segment, additional holes preserve options if error is encountered during inset. Only 2 holes are drilled using the fibula cutting guide to allow the extra holes to be drilled during flap inset if repositioning is needed.

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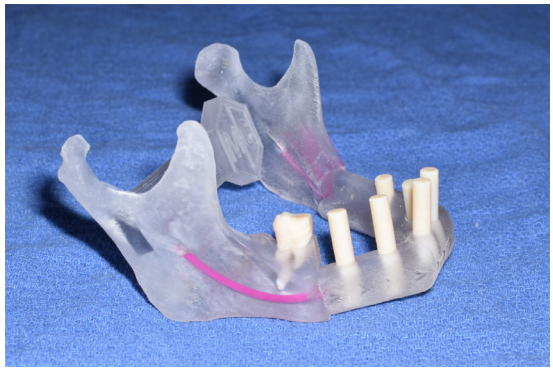

FIGURE 4. Usage of the second molar to establish the proper Vertical Dimension of Occlusion for a full arch restoration. The second molar is removed and aggressive alveoloplasty is performed at the end of the surgery.

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feasible. This allows for a vertical stop to place the prosthesis at the proper VDO (Fig 4). Once the prosthesis is attached to the implants, the second molars are removed and aggressive alveoloplasty is performed. The prosthesis should be removed during second molar extraction. Retaining second molars only creates a hygiene problem adjacent to a tall prosthesis, so the authors prefer to remove these teeth.

FIBULA HARVEST

Minor modifications to conventional fibula harvest techniques are useful. The authors will sometimes allow muscle on the fibula to remain exposed in the

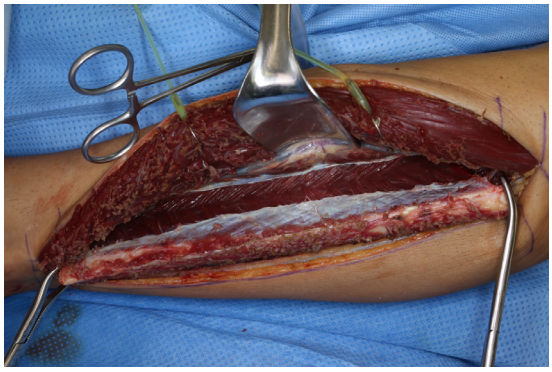

FIGURE 5. The white interosseous membrane has been divided with a 1cm cuff remaining on the fibula to suture to the floor of mouth. The chevron-shaped fibers of the posterior tibialis muscle are seen beneath the interosseous membrane.

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mouth to allow mucosalization. The resulting peri-implant soft tissue is less bulky than a skin paddle and reasonably attached although not necessarily keratinized. To ensure bone does not become exposed, more muscle than usual is left attached to the fibula during harvest.

Many surgeons divide the interosseous membrane close to the fibula. However, we leave a 1cm cuff of the interosseous membrane attached to the fibula. This is oriented to the lingual and provides a durable layer to suture to the floor of mouth during inset allowing mucosalization of the exposed muscle around the implants (Fig 5).

IMPLANT PLACEMENT AND FIBULA OSTEOTOMIES

Once the fibula is harvested and isolated on the vascular pedicle, the flap remains on the leg to perfuse. The fibula cutting guide is secured with screws to the fibula (Fig 6). Implants are placed prior to sectioning the bone since implant placement in dense bone is more difficult once the fibula segments become mobile. Our most common implant size is 3.75 × 13 mm. Implant osteotomies are created all the way through the fibula (bicortical) with drills up to the 3.2 mm diameter. The 3.6mm drill is used only for the upper half of the implant osteotomy. Implants are placed through the guide to a subcrestal depth. After implants are placed, attention is turned to the predictive screw holes which are drilled through the guide. Lastly, the fibula osteotomies are performed. The guide is removed, and implants are verified to be buried subcrestal inside the fibula at proper depth. Special care should be directed to the lingual aspect of the implants to ensure they are subcrestal. This region of the fibula tends to slope downward, and muscle bulk can make visibility difficult. Sometimes a ronguer is used to remove and flatten bone on the buccal aspect if deep implant placement is needed. Alternatively, many implant manufacturers have a bone profiler which can be used. These bone interferences above the implant must be removed to allow seating of the abutments.

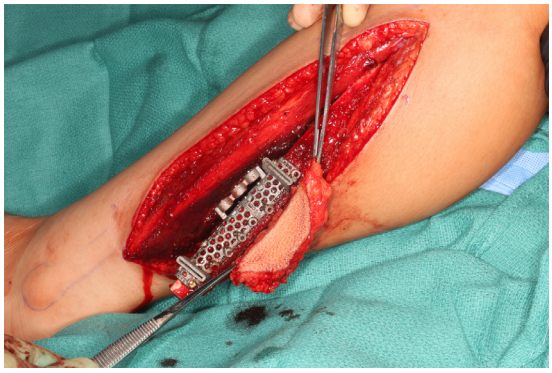

FIGURE 6. Titanium fibula cutting guides in place with space for irrigation. Three implant osteotomy guide holes are seen superiorly.

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Multi-unit abutments (MUAs) are placed on the implants and torqued to the manufacturer's specification. The tallest MUAs available should be used to raise the restorative platform away from the implant platform which should be placed subcrestal. The MUAs also provide a tissue-friendly surface and are kept in place indefinitely to not disturb the implant/abutment interface as the bone and soft tissue heals. The tallest MUAs are sometimes inadequate to compensate for both subcrestal placement and soft tissue thickness. Custom MUAs up to 8mm tall are available from TruAbutment (TruAbutment, Irvine, CA). The authors stock 5 mm and rarely 7 mm straight MUAs from TruAbutment in addition to the standard shorter 3.5 mm MUAs. Although angled MUAs are available, straight MUAs should be planned for to avoid the need for adjustment of implant timing.

ATTACHING THE PROSTHESIS ON THE LEG: THE FLOATING PROSTHESIS

With appropriate models and planning, the dental prosthesis can be luted to the implants while still on the leg. The authors design the dental prosthesis and establish accurate relationships of the prosthesis to the opposing occlusion with Blue Sky Plan software (Blue Sky Bio, Libertyville, IL). The software is free to download and use but charges a nominal fee per patient to export digital files for 3D printing. This prosthesis is designed with an arm attachment to an occlusal splint covering adjacent natural teeth to suspend it in the correct position over the implant temporary copings for pick up. A model of the planned defect allows the fibula to be plated to the model while still at the leg using the milled plate and screws.

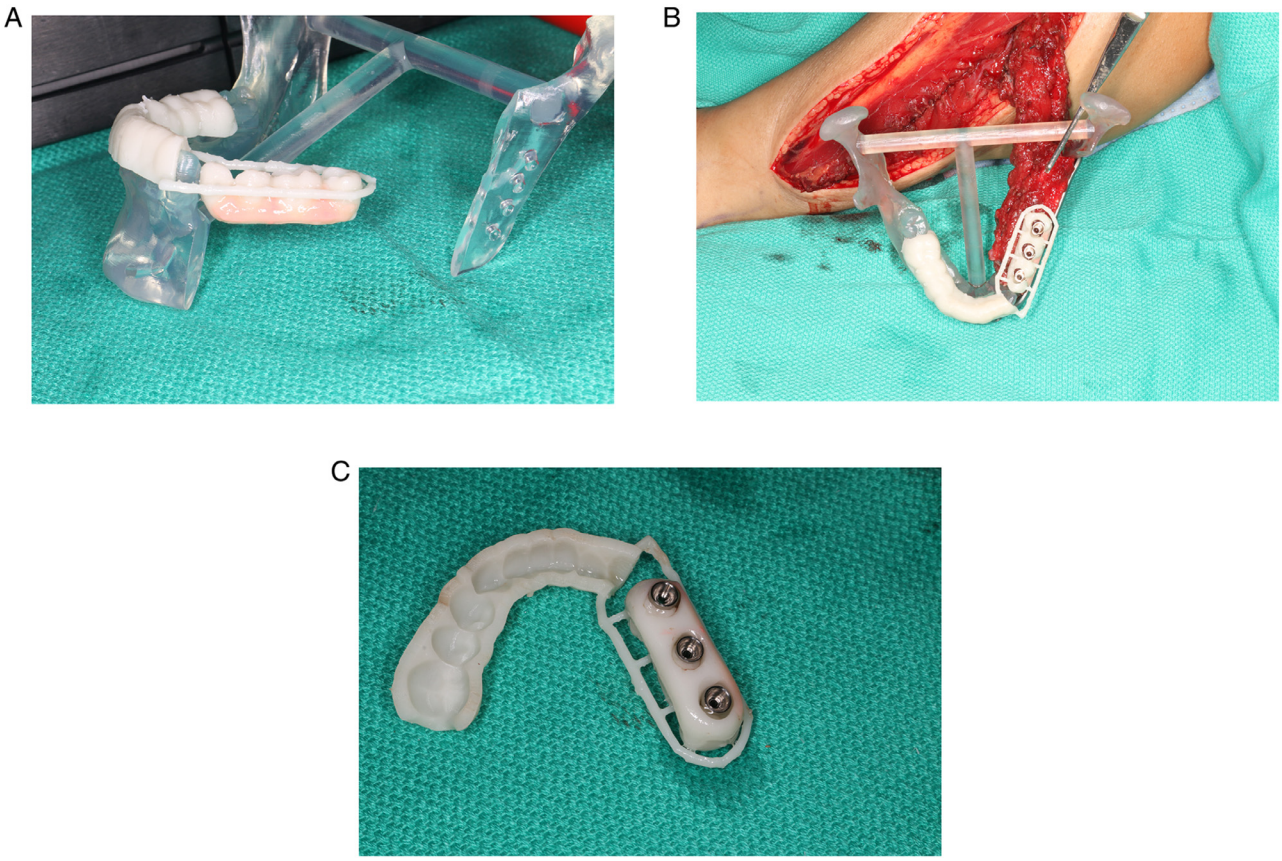

FIGURE 7. (A) The clear model of the planned defect is shown with the "floating prosthesis" placed on the defect model. After placing implants in the fibula and performing osteotomies, the fibula will be fixated to this defect model to allow pickup of the implant copings to be performed on the leg with no need for splints, maxillary models or intermaxillary fixation. (B) The fibula with implants is fixated temporarily on the defect model, with the "floating prosthesis" seated over the implants to pick up the temporary copings and lute them to the prosthesis. (C) Pickup of the copings completed. The "floating prosthesis" is removed for final trimming and to fill in voids with acrylic.

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The floating prosthesis is then placed on the defect model which suspends the new teeth over the implant temporary copings for pickup with acrylic resin (Fig 7A to C).

FLAP INSET

The fibula is inset into the defect using the prefabricated plates and screws in the planned position. If keratinized tissue remains around the defect, this can be sutured around the implant abutments. If the soft tissue is deficient for primary closure but not large enough to warrant a skin paddle, the authors will leave muscle exposed on the fibula to mucosalize. This requires special fixation of the buccal and lingual mucosa. The lingual mucosa and floor of mouth is sutured to the interosseous membrane of the fibula. This is a strong layer which holds sutures much better than muscle and will support a watertight closure. The buccal mucosa is sutured to the fibula bone with transosseous sutures as previously described[8-10] in the implant literature (Fig 8A, B).

Because suturing the buccal mucosa to holes in the bone has the potential to allow leakage of saliva into the neck, an additional layer of closure is performed in the neck just inferior to the fibula. The platysma muscle is sutured to the deep fascial layers in the neck at the level of the inferior border of the mandible. This causes the deep soft tissue to adapt closely to the bone and creates an additional layer of closure (Fig 9). The remainder of the neck is closed in the usual fashion.

In some cases, a skin paddle can be used to augment mucosal deficiencies. Case selection is critical as the surgeon must be able to predict the soft tissue defect. The most appropriate cases for skin paddles involve placing the skin paddle on 1 side of the implants while native mucosa covers the other side. This allows implants to emerge through the suture line and avoids creating perforations in the skin paddle for implant emergence. When using a skin paddle on the buccal aspect, the authors prefer to have it wrap over the plate from below. This creates slight tension which serves to develop a vestibule and minimize bulk around the implants (Fig 10A, B).

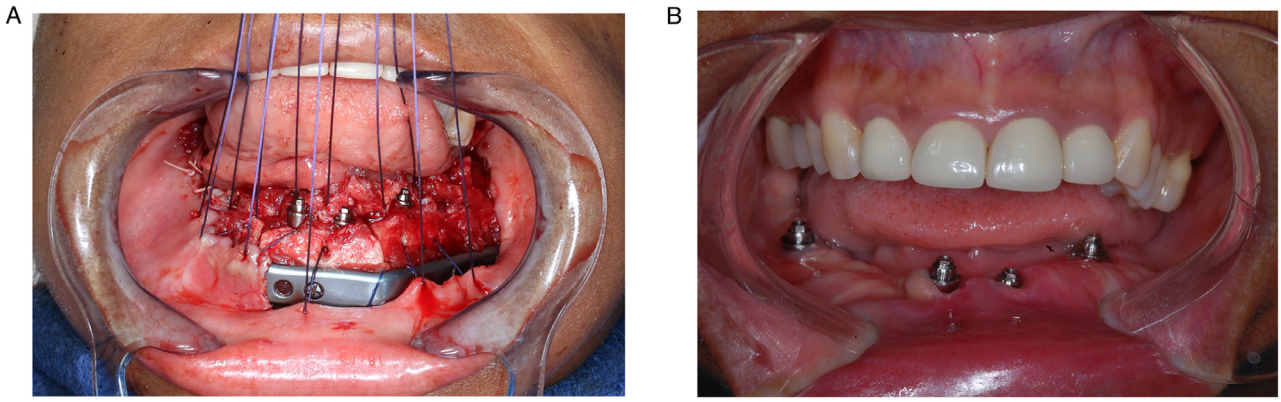

FIGURE 8. (A) Transosseous sutures to allow mucosalization of exposed muscle yet still cover the reconstruction plate. (B) Good healing and mucosalization 4 months after closure using transosseous sutures with exposed muscle on the fibula allowed to mucosalize.

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FIGURE 9. Closure of the deep neck fascia to the platysma to add an additional layer of closure when a watertight oral seal is not accomplished. For photographic purposes, only the patient's right side in this photo has been closed in this manner.

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ATTACHING THE PROSTHESIS IN THE MOUTH

For full arch prostheses, the floating prosthesis is not feasible, and the authors attach the prosthesis to the implants after the fibula is inset in the mouth. This also results in a balanced occlusion since a full arch prothesis cannot be fixated out of occlusion. The process involves seating the prosthesis over the implant temporary copings and injecting a pickup material to connect the temporary copings to the prosthesis. Multiple materials are available which are usually self-curing acrylics. The authors use Luxatemp Ultra (DMG America, Ridgefield Park, NJ) for its ideal handling properties and high viscosity which keeps the material from running into the wound. The material sets while the prosthesis and jaw are held into proper occlusion. For intra-oral attachment of the prosthesis, the authors prefer to only attach the anterior 2 implants at first. Then the posterior implants can be attached with the bite open by injecting through the occlusal surface. The temporary copings

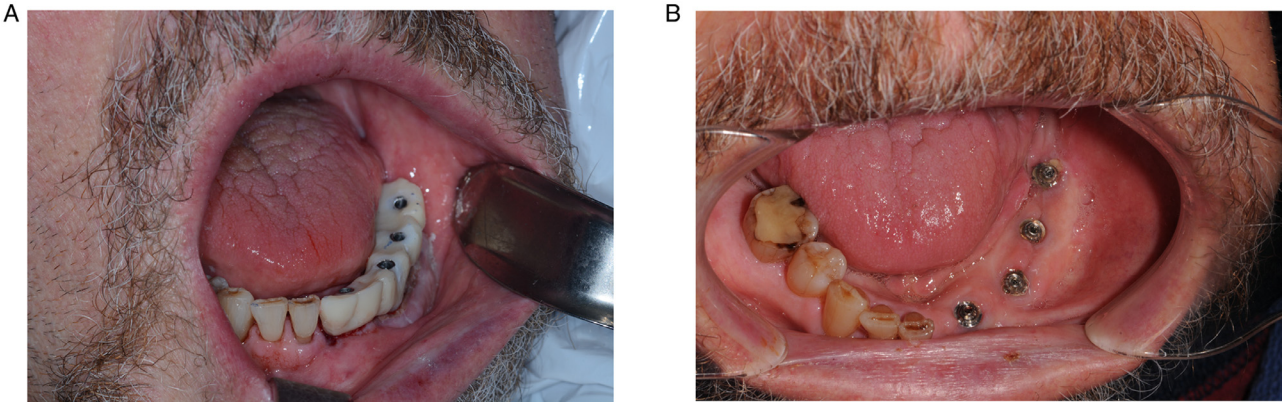

FIGURE 10. (A) Fibula skin paddle healed after 4 months with slight downward tethering to create an adequate buccal vestibule. (B) Same patient after 9 months showing preserved buccal vestibule with the fibula skin paddle.

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FIGURE 11. Markings with occlusal paper for full arch restoration of the mandible with implants in the fibula.

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are unscrewed, and the prosthesis is removed for final shaping and polishing prior to final seating. If natural teeth remain, the prosthesis is verified to be out of occlusion. With a full arch prosthesis, the occlusion should be balanced across the arch with articulating paper (Fig 11). Patients are asked to avoid chewing with their temporary prosthesis until implant integration is verified and their final prosthesis is placed.

Results

Ninety-five implants were placed in 22 patients and followed for a minimum of 3 months (range 3 to 41 months) until implant integration could be verified by torque testing. Patients ranged in age from 13 to 64. There were 14 males and 8 females. Between 3 and 6 implants were placed in each patient. A full arch prosthesis was provided for 8 patients while 14 patients had native teeth remaining. Five implants in 4 patients were not immediately loaded. Of the 22 patients, only 2 patients were maxillary reconstructions. Diagnoses included benign bone tumors in 11 patients, malignant tumors (squamous cell carcinoma and sarcoma) in 6 patients, gunshot wounds in 3 patients, and osteoradionecrosis in 2 patients. Only 4 patients were current smokers. Skin paddles were used in 10 patients to compare with the 12 patients with only mucosa.

Implant success rates were determined with 2 parameters. The first is integration rate which was determined at least 3 months after surgery with torque testing. The second parameter is loss of implants after successful integration (delayed loss) regardless of etiology. Of 95 implants, 3 implants in 2 patients failed to integrate resulting in a 97% rate of successful integration. Of these 2 patients with implants failing to integrate, the first patient had a full arch prosthesis and 1 of her 6 implants did not integrate. Interestingly, this implant was the only implant not loaded in her temporary prosthesis. A second patient had 2 of his 6 implants not integrate with his full arch prosthesis. The temporary prostheses remained and neither of these patients had to function without teeth.

Delayed loss of implants was seen in 4 patients. For our purposes, we define delayed loss as a previously functioning integrated implant which is later removed. Three of these patients each had a single implant removed 9 to 15 months after surgery due to peri-implantitis with thread exposure and progressive bone loss. The fourth patient lost all 4 implants and his prosthesis after developing osteoradionecrosis in his fibula and adjacent mandible beginning 6 months after surgery. This was a single-segment fibula for a lateral mandible defect due to squamous cell carcinoma. His fibula was ultimately removed and replaced with another fibula with immediate implants but not immediate teeth. Accounting for delayed loss of these 7 implants results in an overall 93% success rate. Except for the fibula with osteoradionecrosis, all failed implants were removed in an office setting. Of 6 patients treated for malignancy, 4 patients (13 implants) underwent postoperative radiation. All had successful integration of their implants, but one fibula/implant construct was later lost after developing osteoradionecrosis as detailed above.

Patients with skin paddles were compared to patients with native mucosa only. Native mucosa includes both keratinized and non-keratinized tissue. Ten patients had skin paddles adjacent to implants, compared to 12 patients with native mucosa. All implants adjacent to skin paddles integrated and no delayed implant loss has been recorded yet. Of 10 skin paddle patients, 4 were for malignant disease. Only 3 skin paddles required secondary debulking and none of these patients had to go without their prostheses. Debulking was performed in the office 3 months after surgery while also torquing implants. The procedure consisted of excising an ellipse of skin and subcutaneous fat and suturing closed. Because all implants emerged from the junction of the skin paddle and native mucosa, the ellipse of skin removed was buccal to the implants while skin around the implants remained.

Reactive granulation tissue is a common problem around fibula implants. Of 95 total implants, reactive tissue developed around 10 implants (6 patients) with skin paddles, and 7 implants (4 patients) with native mucosa. While almost half the patients developed reactive tissue, these were mostly isolated to individual implants (18% of all implants), especially

FIGURE 12. Healed skin paddle around multi-unit abutments 4 months after surgery for osteoradionecrosis. The peri-implant skin around the 2 posterior implants appears non-inflamed with no reactive tissue and no erythema. Debulking was performed 1 month prior to this photo and the healing skin incision is noted towards the buccal.

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implants with mobile non-keratinized mucosa. No patients who received postoperative radiation developed reactive tissue. Of the 4 patients who were smokers, none developed reactive tissue. All cases of reactive tissue were managed with removal of the exuberant tissue with a curette followed by silver nitrate cautery. This usually resolved after 1 to 2 sessions, but 2 patients developed persistent reactive tissue leading to peri-implantitis and bone loss requiring removal of an implant.

Discussion

Microvascular jaw reconstruction with immediate teeth was first performed in 2007 by British surgeon Dr. Iain Hutchison and prosthodontist Dr. Andrew Dawood.[11-13] Their surgery involved a scapula, although the fibula is the donor site most used today. While multiple publications have focused on the prosthetic aspects of the surgery, few reports describe the surgical modifications of fibula harvest, implant placement and skin paddle inset that may improve outcomes and versatility.

Immediate dental restoration during fibula reconstruction has previously been recommended for only benign disease.[1,2] Reported concerns for malignancy include uncertainties about radiation effects, the need for skin paddles in many malignant cases, and the additional time required to fabricate the dental prosthesis. Based on our small cohort, postoperative radiation was not associated with decreased rates of implant integration. All radiated implants integrated, and none developed reactive granulation tissue. One patient developed osteoradionecrosis in his fibula and lost his implants when the fibula was removed. Flap loss, regardless of etiology, is a devastating outcome with emotional and financial implications when dental implants are involved.

Since many malignant cases require skin paddles, immediate dental restoration has been limited to benign diagnoses. We have found success in skin paddles with all 36 implants integrating in 10 patients. Of 95 implants, reactive tissue was noted around 10 skin paddle implants compared to 7 implants with native mucosa, although the sample size is too small for meaningful statistical analysis. While keratinized attached gingiva is the first choice of soft tissue implant coverage, we prefer skin over nonkeratinized mobile mucosa. Skin seems less mobile than nonkeratinized mucosa which may contribute to its improved tolerance of an abutment and prosthesis (Fig 12). Patient selection is critical when attempting an immediate dental prosthesis with a skin paddle, and the surgeon must anticipate the soft tissue defect. The authors choose defects expected to allow implants to emerge through the suture line between the skin paddle and native mucosa. The primary disadvantage of skin paddles is the potential need for debulking later. Of our 10 skin paddle cases, 3 required secondary debulking.

The final reason immediate dental prostheses have been recommended only for benign disease is the additional time required to create the teeth. In addition to the 2 to 3 weeks required for Virtual Surgical Planning (VSP) and creation of custom plates and models, an additional 2 to 3 weeks is requested for current commercially available dental labs. Most surgeons do not want to delay oncologic surgery these additional weeks just for teeth. Our group participates in the VSP session to determine implant positions along with fibula placement, then designs and 3D prints our own provisional teeth the next day. Any surgical delay due to teeth is eliminated. Our digital workflow has been previously described.[4] In this series, no patients experienced a delay in surgery waiting on their dental prosthesis, and no patients were delayed in beginning adjuvant radiation therapy due to implant/prosthetic issues.

For successful prosthetic outcomes, planning should be restoratively driven. This requires placement of bone in proper orientation with the opposing dental arch for optimal implant positioning. Soft tissue health is vital for long-term success to mitigate against peri-implantitis. Depth of implant placement should account for expected marginal bone loss to avoid exposed threads and peri-implantitis.[14]

While the intricacies of implant placement in fibulas are commonly discussed, the importance of abutment selection is rarely reviewed. The authors use multi-unit abutments (MUAs) on all cases which provide multiple advantages. MUAs allow for deeper

implant placement by raising the restorative platform above the bone level, resulting in easier hygiene and maintenance. MUAs also move the inherent misfit of these prostheses from the implant level to the abutment level. A randomized controlled trial has shown this results in reduced marginal bone loss.[15] MUAs allow for platform switching which is otherwise not possible when connecting non-parallel implants. Platform switching has been shown to decrease marginal bone loss.[16] While preoperative virtual planning should incorporate straight MUAs, angled MUAs are available to correct for malpositioned implants if needed. Finally, MUAs allow placement of the definitive abutment at the time of implant placement which may further decrease marginal bone loss.[17]

The creation of stable soft tissue around the transmucosal portion of the implant is critical to the long-term implant health. This biologic seal preserves crestal bone levels, supports peri-implant soft tissues, and provides a soft tissue seal against microorganisms.[18] The transmucosal component (the abutment) is ideally placed only once and never removed. This one abutment − one time concept relies on the maintenance of a stable soft tissue attachment to the abutment. Repeated removal and replacement of the abutment disrupts the soft tissue attachment and leads to additional marginal bone loss.[17,19,20] A multi-unit abutment best accomplishes these goals.

Implants lost in this series were both early (failure to integrate) and late (peri-implantitis and osteoradionecrosis). Four of the 7 implants lost after integration were due to osteoradionecrosis of the vascularized fibula in a single patient, a rare complication.[21] The other 3 implants were lost to peri-implantitis in 3 other patients. Because peri-implantitis may develop even years after placement, it is possible currently healthy implants could develop peri-implantitis in the future and be lost. Therefore, long-term assessment of these implants will be needed to know the true implant survival. This is particularly true in oncologic patients where the effects of postoperative radiation last for the remainder of the lifetime. The 6 oncologic patients in this series have been followed for a range of 6 to 24 months.

While implant success is often a primary focus, prosthetic success is rarely reviewed. In this cohort of 22 patients, all but 1 patient has transitioned to their final prosthesis or are in the process with their restorative dentist. One patient has remained in his full arch provisional prosthesis for 20 months due to financial restraints after losing his employment during the COVID-19 pandemic. Financial commitments for both surgical and prosthetic aspects are discussed in detail prior to treatment for every patient. This patient was also the only patient to fracture his prosthesis approximately 12 months after surgery.

Meaningful statistical analysis is difficult with only 22 patients. While the authors' recommendations are based on common understanding of implant biology, immediate provisionalization in fibulas involves non-traditional soft tissue characteristics not well studied. Continued follow-up over many years will be beneficial to understand the bone and soft tissue implications of our current techniques. We hope this article will serve as a reference for further studies.

Press Release

This article's Press Release can be found, in the online version, at http://dx.doi.org/10.1016/j.joms.2021.04.005.

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