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Free flap jaw reconstruction with dental implantation: A single-institution experience

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Abstract

Background: We sought to review our institution's experience with dental implant placement in free flap jaw reconstruction to determine factors impacting restoration of dental occlusion.

Methods: Exactly 48 patients underwent free flap jaw reconstruction with or without dental restoration from 2017 to 2022. Primary outcome was achievement of restored dental occlusion after jaw free flap reconstruction.

Results: A total of 48 patients with a mean age of 59.8 ± 16.4 years underwent jaw reconstruction from 2017 to 2022. Ten patients (20.8%) received osteointegrated dental implants. Two patients received a temporary dental prosthesis, 12 ± 4 months after initial reconstruction. Three patients received a final prosthesis, with a mean time to final prosthesis of 17.7 ± 12.4 months. Five patients did not receive any prosthesis despite placement of implants.

Conclusion: A minority of patients received dental implant placement with free flap jaw reconstruction and only a small subset of these received a definitive dental prosthesis.

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AUTHOR CONTRIBUTIONS

Benjamin T. Ostrander was involved in design, conduct, analysis, and presentation. Leo Meller was involved in conduct and analysis. Matthew Harmon was involved in conduct. Katya Archambault was involved in design, conduct, and analysis. Daniel Hammer was involved in design, conduct, analysis, and presentation. Ryan K. Orosco was involved in design, conduct, analysis, and presentation.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to disclose.

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Keywords

dental implants; dental reconstruction; free fibula flap; head and neck surgery; jaw reconstruction

1 | INTRODUCTION

Surgical treatment of head and neck malignancy often results in debilitating defects of the mandible and maxilla. These defects can have an enormous impact on an individual's dentition, speech, swallowing, nutrition, social functioning, and appearance. Consequently, reconstruction aimed at restoring both form and function is paramount to preserving quality of life after cancer treatment.

Numerous approaches to reconstruction have been used in these patients, including free bone grafts, reconstruction plates, local flaps, regional pedicled flaps, and free tissue transfer.[1] Microvascular free flaps containing vascularized bone are the most effective at restoring form and function and are the standard for most jaw reconstructions today.[2] In particular, the fibula free flap popularized by Hidalgo in 1989 has proved invaluable for mandible and maxilla reconstruction.[3]

The ideal functional jaw reconstruction restores the jaw relationship, continuity, facial contour, joint alignment, nasal patency, lacrimal function, and orbital integrity.[1] A critical component of oral rehabilitation involves the restoration of dental occlusion. Historically, most jaw reconstruction has not included dental implantation. An analysis of 64 cases of primary mandibular reconstruction published in 1991 demonstrated that only four patients were able to wear a dental plate, all of whom had more limited resections confined to the alveolus.[4] In a case series of jaw reconstruction using free fibulas in 31 patients published in 1998, only 16 patients received dental implants, all in delayed fashion.[5]

In recent years, dental rehabilitation as a component of jaw reconstruction is increasing in popularity, due in part to advances in technology and technique as well as growing recognition that functional jaw reconstruction requires re-establishing dentition. Osteointegrated implant technology has revolutionized dental occlusal reconstruction and provides the most reliable method of dental rehabilitation in patients with jaw defects.[1,6,7] Despite the successes of free flap reconstruction and osteointegrated dental implants, most reconstructions do not establish timely functional restoration.[8-10]

The spectrum of jaw reconstruction with dental rehabilitation varies widely today. Many patients never receive dental rehabilitation, and the resulting reconstruction leaves them edentulous and requiring a soft diet for life.[5] For patients that do receive dental rehabilitation, this has historically involved placement of osteointegrated implants in a delayed fashion. A retrospective study published in 2017 involving 22 patients over 14 years found that most patients ($n = 19$) underwent dental implant placement as a secondary surgery, which was performed 7–24 months (mean 11 months) after FFF reconstruction.[11] Primary placement of dental implants at initial reconstruction was validated by Urken et al. more than 20 years ago, but has only recently gained more widespread use, especially in cancer cases.[8,12-14] This technique typically requires delayed secondary vestibuloplasty to expose the implants before placing a prosthesis. In 2013, Levine et al. demonstrated proof of concept for jaw reconstruction with functional dental rehabilitation through a single operation, a technique they called “Jaw in a Day” (JIAD).[15] Although it has been nearly a decade since the JIAD technique was introduced, it is rare for patients to receive immediate dental implants or an immediate prosthesis at the time of initial surgery.[10,16] At most centers, dental rehabilitation usually requires 6–12 months before it is completed.[17]

We sought to review our institution’s experience with jaw reconstruction and our progression toward advanced rehabilitation techniques, with attention toward barriers to achieving timely dental rehabilitation. We present a cohort study involving 48 jaw reconstructions with free tissue transfer to the mandible performed over a 6-year period, of which only a small subset received dental rehabilitation as part of their reconstruction.

2 | MATERIALS AND METHODS

Approval for this cohort study was obtained from the University of California San Diego Institutional Review Board. The study population comprised of sequential cases of maxilla or mandible reconstruction from September 2017 to June 2022, with most patients requiring reconstruction due to malignancy. A manual record review in 54 subjects was performed by three co-authors. Six patients who underwent free tissue transfer were excluded because they did not undergo mandible or maxilla reconstruction. Demographic data, past medical history, clinical history, operative details, post-operative course, and outpatient follow up were reviewed in detail.

All jaw reconstructions were performed by the senior author. Primary outcome was achievement of restored dental occlusion after jaw free flap reconstruction at most recent follow up. Occlusion was defined by the presence of functional dental contact between native teeth and dental prosthesis. Secondary outcomes included primary placement of osteoingegrated dental implants, need for vestibuloplasty or intraoral flap debulking, reconstruction (including flap) type, use of virtual surgical planning (VSP), and complications including flap failure. Dental implantation was offered on a case-by-case basis depending on the patient’s pre-operative clinical and functional status, anticipated surgical defect and reconstructive approach, treatment motivations, and financial considerations. Given our experience, this translated to patients receiving mandible reconstruction with fibula free flaps who had the financial means, as dental care is frequently not covered by medical insurance. Statistical analysis was performed using Microsoft Excel and Stata.

3 | RESULTS

The cohort characteristics, including patient demographics and surgical characteristics, are detailed in Table 1. Forty-eight patients with a mean age of 59.8 ± 16.4 years underwent free flap reconstruction of the mandible or maxilla from September 2017 to June 2022. Thirty-seven patients (77.1%) had active malignancy, and 11 patients (22.9%) underwent jaw reconstruction for other indications, most commonly osteoradionecrosis. Thirty-two patients (66.7%) were male. Mean body mass index (BMI) was 27.9 ± 7.5 kg/m^2. The most common comorbidities were hypertension (43.8%), tobacco use (25.0%, >10 pack-year history), and diabetes mellitus (14.6%). A third (35.4%) had a history of prior chemotherapy, radiation, or both. Patients who underwent jaw reconstruction who did not have an active malignancy were more likely to have a history of prior adjuvant therapy (72.7% vs. 24.3%, $p = 0.003$). Hyperbaric oxygen therapy (HBOT) was administered before surgery in 18.8% of cases, more commonly in patients without active malignancy (63.6% vs. 5.4%, $p < 0.001$). In terms of dental implantation, osteointegrated implants were placed at the time of initial reconstructive surgery in 10 patients. Those receiving implants tended to have younger age, male sex, and lower BMI.

Surgical characteristics and post-operative course are summarized in Table 2. Isolated segmental mandibulectomy (without external defect) was the most common surgical defect, in 35 patients (72.9%)—which comprised 6 of the 10 patients (60.0%) receiving dental implants. In our cohort, no maxillectomy defect cases received osteointegrated implants. Virtual surgical planning (VSP) was used in 47.9% of cases. Of note, VSP was used in 9 of 10 patients receiving osteointegrated implants, at a significantly higher rate than for non-implant cases ($p = 0.003$). An example of VSP is illustrated in Figure 1. The fibula free flap was most used for reconstruction (72.9%), followed by the osteocutaneous radial forearm free flap (25.0%). All patients receiving dental implants had mandible reconstruction using a fibula free flap. For these cases, the fibula was always oriented with the anterior aspect at the alveolus, avoiding placement of implants posteriorly where the perforators are located. Mean case length, including ablation or resection when applicable, was 482 ± 173 min, with longer case lengths for those with active malignancy (512 ± 161 min vs. 381 ± 181, $p = 0.02$). Case length for those receiving implants was not significantly longer ($p = 0.19$).

Mean hospital length of stay was 10.0 ± 5.2 days and mean duration of follow up was 16.4 ± 15.2 months. Length of stay was not significantly longer for those receiving dental implants ($p = 0.28$). Patients with malignancy had a significantly longer duration of follow up (18.6 ± 15.7 vs. 6.9 ± 5.3 months, $p = 0.02$), limited by study duration. Of those with cancer, 26 patients (61.9%) underwent adjuvant radiotherapy, with a mean time to radiation of 56.9 ± 21.8 days, based on available data from 24 patients. Time to radiotherapy was not negatively impacted by osteointegrated implant placement, with mean time to radiotherapy at 49.4 ± 10.1 days versus 58.9 ± 23.8 respectively, for the implant compared with the no implant group ($p = 0.40$). Thirteen patients (27.7%) had post-operative HBOT, with significantly more patients without active malignancy receiving this ($p = 0.08$). HBOT was also common in the implant group, with 70% receiving post-operative HBOT at some point during the follow up period. Ten patients (25.6%) had cancer recurrence. Flap failure occurred in a 74-year-old male with multiple comorbidities (hypertension, coronary artery disease status post percutaneous coronary intervention and coronary artery bypass graft surgery, chronic obstructive pulmonary disease, chronic kidney disease, deep venous thrombosis, carotid stenosis status post carotid endarterectomy, and transient ischemic attack) who developed metastatic disease shortly after surgery. An additional patient had partial flap loss of the skin paddle only that was treated with a split thickness skin graft, and this was not included as a complete flap failure. Two patients required take backs to the operating room for anastomosis revisions, both of which were successful. Infection occurred in 12 patients

(25.0%). Exposed hardware occurred in 4 patients (8.3%) and hematoma/bleeding occurred in 1 patient (2.1%).

Dental reconstruction characteristics and outcomes for the patients receiving osteointegrated implants are detailed in Table 3. No patients underwent immediate dental rehabilitation with prosthetic teeth. Ten patients (20.8%) received osteointegrated dental implants, of which all were placed immediately at the time of free flap reconstruction. However, one patient had four implants placed at the time of reconstruction with an additional two implants placed during a second stage procedure at a later date. Five had reconstruction for malignancy and five for osteoradionecrosis or benign neoplasm, with patients without active malignancy more likely to receive implants ($p = 0.02$). Forty-two total implants were placed, and a mean of 4.2 ± 1.8 implants were placed per patient, with no significant difference in the number of implants between groups ($p = 0.35$). Four patients (40.0%) underwent vestibuloplasty or debulking to access the implants, 11 ± 6.7 months after primary surgery. Three patients had complications, all of which occurred in the malignancy group. One had osteoradionecrosis with hardware infection that required removal of hardware, after which the fibula reconstruction shifted position inferiorly resulting in extrusion of one of the implants through the neck skin. Another had recurrent infections ultimately requiring hardware removal, and the third had poor osteointegration of several implants. Two patients received a temporary dental prosthesis, 12 ± 4 months after jaw reconstruction. Three patients received a final prosthesis, with a mean time to final prosthesis of 17.7 ± 12.4 months. These prostheses were functional and allowed patients to eat a normal diet. Of these, two never received a temporary prosthesis. Two patients had non-implant supported removable partial dentures. Five patients did not receive a prosthesis despite placement of osteointegrated implants at the time of initial surgery, due to multifaceted issues including loss to follow up, inability or unwillingness to pay for additional dental care.

In summary, 5 of 37 patients (13.5%) with malignancy and 5 of 11 patients (45.5%) without malignancy received implants at the time of surgery. To our knowledge, no patients in our cohort had implants placed in a delayed fashion. Exactly 38 of 48 patients (79.2%) never received dental implants. Only 3 of 48 patients (6.3%) received a final dental prosthesis, accomplishing functional occlusal dental reconstruction.

4 | DISCUSSION

As we have pursued advanced dental reconstruction through our practice at a National Cancer Institute (NCI)-designated Comprehensive Cancer Center, we have learned a great deal. In this cohort study of 48 patients undergoing jaw free flap reconstruction, 10 patients received osteointegrated implants at the time of initial reconstruction, and only 3 ultimately received a final prosthesis (6.3% of total, 30% of implanted patients). Interestingly, even among the small portion of patients who received osteointegrated implants (10 of 48 total), less than half have had these implants used for temporary or permanent prostheses. Two of the 3 patients who received a final prosthesis never received a temporary one, and the time to receipt of either a temporary or final prosthesis was more than 1 year. These figures highlight several challenges and barriers to occlusal dental rehabilitation. Due to these challenges, functional dental restoration remains largely aspirational at all but a few specialized centers across the United States.

It is well established that occlusal reconstruction is a cornerstone of functional restoration. It has been shown to improve masticatory efficiency, speech function, and patient-reported quality of life.[13,18] The advantages of immediate dental rehabilitation include a decrease in the number of surgeries and expedited return to true form and function.[10] Why, then, does dental rehabilitation remain so elusive?

There are many barriers to dental rehabilitation, spanning technical, socioeconomic, and logistical. Dental rehabilitation for complex jaw reconstruction requires specialized training and multidisciplinary collaboration. Achieving proper spatial relationships during complex reconstruction requires experience and careful planning.[1] In our experience, an occlusion-driven reconstruction has the highest chance of accomplishing functional oral rehabilitation.

In our series, 20.8% of patients undergoing jaw reconstruction received osteointegrated implants, all at the time of primary reconstruction. There have been concerns about placing implants at the time of reconstruction due challenges with proper implant positioning, concerns about achieving a water-tight closure and skin paddle survival, and reservations about the integration rate of implants in patients receiving post-operative radiation. However, these concerns have been allayed as immediate dental implant placement into vascularized fibula flaps has been shown to be feasible and safe, for decades.[2,19] There may also be benefits to immediate implantation with regards to improving patient nutrition and reducing cachexia, especially through adjuvant treatment. Prior studies have noted improved quality of life in head and neck cancer and edentulous patients who receive dental implants, as well as reduced risk for malnutrition. However, the relationship between early implantation and reduced cachexia in head and neck cancer patients receiving dental reconstruction has yet to be fully established.[20-22]

The decision to proceed with osteointegrated implants in select patients in our cohort was multifactorial and multidisciplinary. Among the 10 patients who received them, half underwent reconstruction after oncologic resection, and the other half had osteoradionecrosis or benign disease. These patients were offered implants based on their baseline health status including comorbidities, their motivation and willingness to proceed with dental implantation and subsequent follow up, and their ability to pay for the additional procedure. At our institution, we do not plan for dental implantation into bone that has already been irradiated, with a preference for implantation at the time of initial free flap reconstruction. In all cases, the senior author oriented the fibula with the anterior aspect at the alveolus, avoiding placement of implants posteriorly where perforators are located. The bone reconstruction plan is the same for malignant and benign cases. We tend to be more generous with the skin paddle for oncologic patients due to anticipated tissue contraction related to adjuvant radiation. Additionally, the timing of vestibuloplasty to access osteointegrated implants if buried under the skin paddle is different for benign versus oncologic cases. For benign cases, implants can be accessed via vestibuloplasty 2 months after initial reconstruction, but for malignant cases it is recommended to wait at least 4–6 months after the completion of adjuvant therapy.

A significant overarching concern is financial. Dental implants are typically billed outside of surgical fees and are usually not covered by dental or medical insurance. This necessitates out of pocket expenses for the patient to cover the hardware, pre- and post-implant care, and outpatient prosthetic charges. This remains a significant barrier to widespread use in the United States.

Hyperbaric oxygen therapy can be a useful adjunct in patients with osteoradionecrosis or poor healing perioperatively. In this cohort, 27.7% of patients underwent post-operative HBOT, with this being more common in those who received osteointegrated implants (7 of 10 patients). Indications for HBOT included free flap salvage, poor wound healing, recurrent infection, osteonecrosis, and osteomyelitis. Of the seven patients who received HBOT in the osteointegrated group, three were patients who underwent surgery for malignancy, with concurrent reconstruction and dental implantation. While there are concerns about the impact on cancer recurrence with use of HBOT in patients with recently treated malignancy, this treatment is often used to manage radiation-induced complications.[23] The three patients with malignancy who underwent HBOT in our cohort all had significant wound healing issues after adjuvant radiation, with chronic recurrent infections and exposure of hardware.

Proper spatial arrangement of implants at the time of primary surgery has been improved through virtual surgical planning (VSP), which has allowed for predictable fibula positioning in ideal restorative positions.[19] Through the digital VSP process, surgery is planned and simulated virtually then translated back to a physical plan that can be implemented in the operating room through various tools and guides, such as medical models, cutting guides, external fixators, and osteointegrated implant drilling guides.[1] In our cohort, virtual surgical planning was used in 47.9% of cases. Notably, VSP was used at our institution in nearly all (90%) of cases where osteointegrated were placed. However, of these approximately half of the implants were placed using VSP guides, with the remaining implants placed free hand. Over time, guided implantation was used more frequently as the team became more facile with design and use of the implant guides.

Over the course of our own experience with dental implantation into bony free flaps, we have learned several techniques and principles. One of the most important planning tips is to abandon the mantra of putting the inferior edge of the fibula bone along the ideal lower mandible contour. Instead, we place the fibula in a position that is more ideal for occlusal restoration. This means that there will often be a step off along the anterior mandibular body, where the native mandible is more inferior than the fibula. We aim to have 15–18 mm of space between the superior surface of the mandible and the occlusal surface of the upper dentition, which is decided with collaboration with the prosthetics team. Another important point is to place the osteointegrated implant into the anterior surface of the fibula instead of the posterior surface of the fibula. This necessitates using the opposite leg that would ordinarily be used. We have also found it quite helpful to bring the septum up, laterally over the plate, so that the natural pole of the scar creates a lateral gingivolabial or gingivobuccal vestibule. Another technique we learned pertains to the process of vestibuloplasty. Initially, when we returned to access the implants, we had some challenges because we did not place a healing abutment on the implant, and therefore the metal was flush with the bone, making it quite hard to identify and necessitating a much larger skin incision. We now use 4 mm healing abutments so that we can feel the location of the buried implants under the skin paddle and either make a much smaller incision in the operating room to access them or even use punch biopsy scalpel to remove the overlying skin and access them in clinic. It can be particularly dangerous to make large incisions in the skin paddle, especially after radiation, because that can lead to significant retraction of the soft tissue.

As for the effects of radiation, adjuvant radiotherapy has not been associated with decreased rates of implant integration, with increasing evidence supporting immediate implantation in this patient group.[10,17,24-26] Until recently, most centers have elected to place implants after adjuvant radiation, due to concerns about the potential for bone loss around the implants or compromise of the flap skin island needed for oral lining replacement.[27] These concerns have largely been allayed through retrospective clinical reviews focused on early dental implantation, with multiple institutions demonstrating equal or higher rates of implant survival, similar complication rates, improved quality of life, and no delays in initiation of adjuvant radiation.[14,25-27] Furthermore, delaying dental implantation leads to prolonged dental rehabilitation time and risks of poor osteointegration or osteonecrosis in radiated mandible bone. The risk of placing osteointegrated implants after radiation may actually be higher than placing them in healthy, non-irradiated bone. Results in our cohort were in agreement with this evolving paradigm. Of those that received implants in this study, all were placed at the time of initial surgery, and this did not increase length of stay or time to radiotherapy. Forty-two implants were placed, with three patients having implant complications. One had osteoradionecrosis with hardware infection that required removal of hardware, after which the fibula reconstruction shifted position inferiorly. Another had recurrent infections ultimately requiring hardware removal, and the third had poor osteointegration of several implants. Additionally, in our experience skin paddles and water-tight closure can be obtained with immediate dental rehabilitation when designed properly.[10]

Even with occlusion-driven reconstruction and immediate placement of osteointegrated implants, a dental prosthesis must be created to restore dental function. Until recently, design and fabrication of a custom dental prosthesis took weeks to months to complete, a delay that was deemed unacceptable, particularly in cancer patients. Yet by leveraging point-of-care 3-dimensional (3D) printing, an immediate provisional dental prosthesis can be fabricated and ready within 24 h of the VSP session.[10] Consequently, the most efficacious and timely methodology for restoring form and function of the jaw involves immediate, occlusion-driven dental rehabilitation with osteointegrated implants and a provisional prosthesis at the time of primary surgery. This “Jaw in a Day” technique, which accomplishes functional jaw and dental reconstruction within a single procedure, is made possible by leveraging emerging technologies including virtual surgical planning and in-house 3D printing.[10,17,19,24,25,28]

In this series, we did not attempt “Jaw in a Day” reconstruction. The two patients that received a temporary dental prosthesis did so 12 ± 4 months after jaw reconstruction. Three patients received a final prosthesis, with a mean time to final prosthesis of 17.7 ± 12.4 months. Of these, two never received a temporary prosthesis. These numbers highlight a key area for improvement in our workflow, with unacceptable delays to receiving custom dental prosthetics, even temporary ones. Our current workflow involves collaboration with affiliated dental surgeons and outsourcing of the dental prosthetic from a remote fabrication facility. This combined with the logistics and challenges of ongoing cancer treatment, as well as the potential for complications related to surgery or recovery from treatment, can all lead to significant delays. Additionally, no patients in the cohort received delayed osteointegrated implants, which may be related to practice patterns or limitations at our institution and represent another area of improvement.

This study has several weaknesses. The experience of a single surgeon at a single institution is reviewed, which carries inherent biases and limits generalizability. The study was retrospective and based on chart review, and the sample size of patients who underwent dental implantation was small. Therefore, only descriptive trends and inferences could be made. Regardless, the experience presented here is valuable for reviewing a real-world jaw reconstruction experience and understanding the barriers toward achieving dental rehabilitation in jaw reconstruction.

Even with many challenges, the importance of functional occlusal reconstruction for those requiring jaw reconstruction cannot be overstated. The technology and workflow to accomplish prompt and efficacious dental rehabilitation is established, accessible, and is not cost prohibitive. We strive to make these techniques better understood and more widely available so that more patients can maintain their quality of life after life-altering surgical resections.

5 | CONCLUSION

A minority of patients received dental implant placement with free flap jaw reconstruction and only a small subset of these went on to obtain a definitive dental prosthesis. There are many challenges to achieving dental rehabilitation, and additional efforts to understand and overcome patient, institutional, and systemic barriers are needed.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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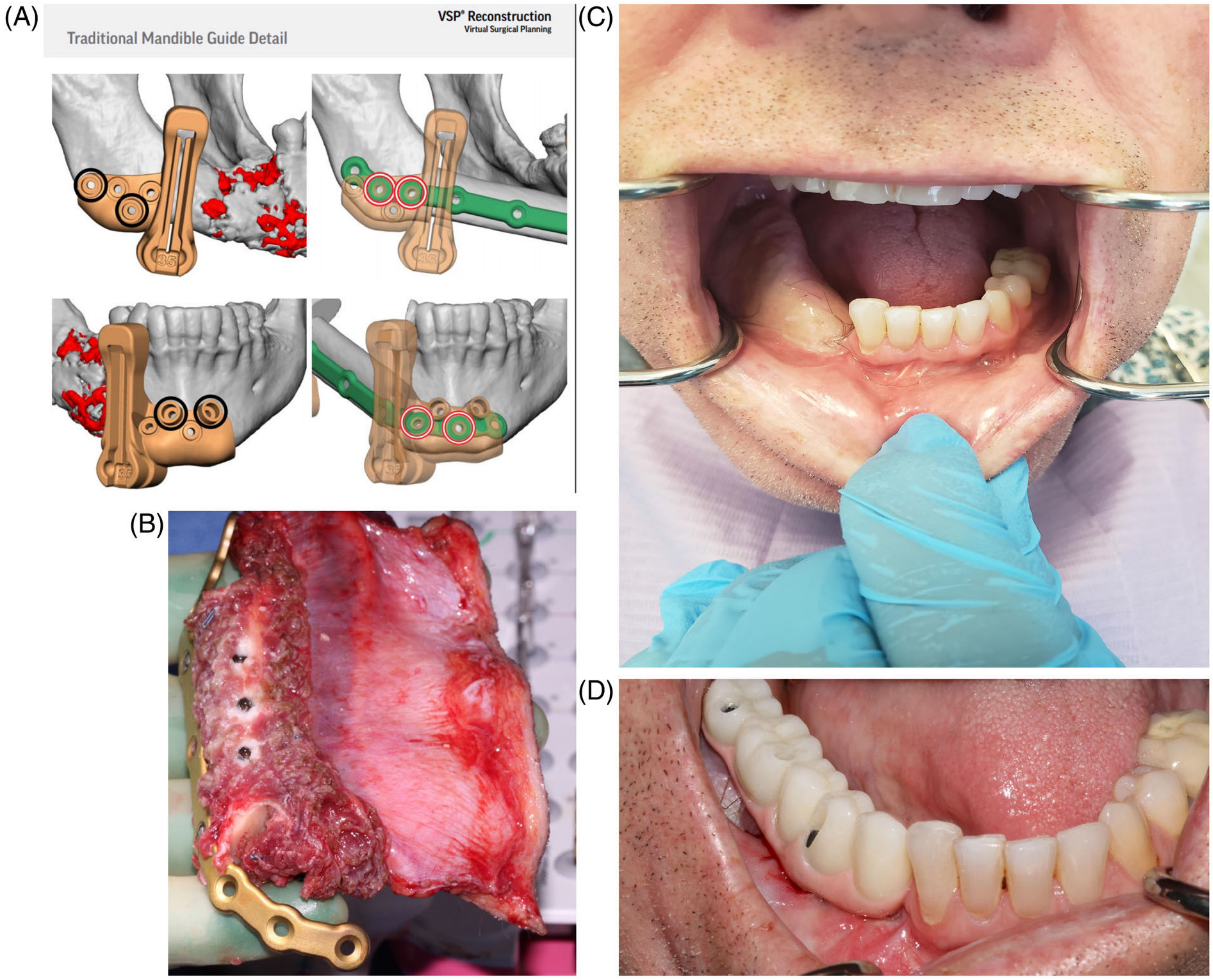

FIGURE 1.

Example of a mandibular reconstruction utilizing a virtual surgical plan (VSP), osteointegrated dental implants, and a dental prosthetic for a neoplasm of the right mandibular body. (A) Virtual Surgical Plan with free fibula flap cutting guides and custom reconstruction plate. (B) Placement of osteointegrated implants into fibula free flap bone. (C) Post-operative photograph of the mandibular reconstruction before vestibuloplasty to expose the implant posts. (D) A custom dental prosthetic is fastened to the exposed osteointegrated posts, restoring functional dental occlusion.

TABLE 1

Cohort characteristics.

Demographics	**Total (n = 48)**	**Malignancy (n = 37)**	**No malignancy (n = 11)**	***p* value**	**Dental implants (n = 10)**	**No dental implants (n = 38)**	***p* value**
Age (years)	59.8 ± 16.4	59.4 ± 16.6	59.5 ± 16.5	$p = 0.96$ (t test)	52.2 ± 21.2	61.8 ± 14.6	$p = 0.10$ (t test)
Male sex	32 (66.7%)	24 (64.9%)	8 (72.7%)	$p = 0.63$ (χ^2)	9 (90.0%)	23 (60.5%)	$p = 0.08$ (χ^2)
BMI (kg/m^2)	27.9 ± 7.5	28.4 ± 8.3	26.3 ± 3.6	$p = 0.44$ (χ^2)	25.2 ± 6.3	28.6 ± 7.7	$p = 0.11$ (χ^2)
Smoking (>10 pack-years)	12 (25.0%)	10 (27.0%)	2 (18.2%)	$p = 0.55$ (χ^2)	2 (20.0%)	10 (26.3%)	$p = 0.68$ (χ^2)
Alcohol abuse	1 (2.1%)	0 (0.0%)	1 (9.1%)		1 (10.0%)	0 (0.0%)	
Co-morbidities							
Hypertension	21 (43.8%)	16 (43.2%)	5 (45.5%)	$p = 0.90$ (χ^2)	4 (40.4%)	17 (44.7%)	$p = 0.79$ (χ^2)
Diabetes	7 (14.6%)	7 (18.9%)	0 (0.0%)	$p = 0.12$ (χ^2)	0 (0.0%)	7 (18.4%)	$p = 0.14$ (χ^2)
Heart disease	4 (8.3%)	3 (8.1%)	1 (9.1%)	$p = 0.92$ (χ^2)	0 (0.0%)	4 (10.5%)	$p = 0.28$ (χ^2)
COPD/asthma	4 (8.3%)	2 (18.2%)	2 (5.4%)	$p = 0.18$ (χ^2)	1 (10.0%)	3 (7.9%)	$p = 0.83$ (χ^2)
ASA class	2.83 ± 0.5	2.8 ± 0.5	2.8 ± 0.4	$p = 0.90$ (t test)	2.7 ± 0.5	2.9 ± 0.5	$p = 0.32$ (t test)
Neo-adjuvant therapy	17 (35.4%)	9 (24.3%)	8 (72.7%)	**$p = 0.003$ (χ^2)**	5 (50.0%)	12 (31.6%)	$p = 0.28$ (χ^2)
Prior HBOT	9 (18.8%)	2 (5.4%)	7 (63.6%)	**$p < 0.001$ (χ^2)**	4 (40.0%)	5 (13.2%)	$p = 0.90$ (χ^2)

Note: Bold values are statistically significant.

TABLE 2

Surgical characteristics and post-operative outcomes.

Surgical outcomes	**Total (n = 48)**	**Malignancy (n = 37)**	**No malignancy (n = 11)**	***p* value**	**Dental implants (n = 10)**	**No dental implants (n = 38)**	***p* value**
Location of defect				$p = 0.39$ (χ^2)			$p = 0.34$ (χ^2)
Segmental mandibulectomy	35 (72.9%)	28 (75.7%)	7 (63.6%)		6 (60.0%)	29 (76.3%)	
Segmental mandibulectomy with external defect	4 (8.3%)	2 (5.9%)	2 (14.3%)		2 (20.0%)	2 (5.3%)	
Hemimandibulectomy	5 (10.4%)	1 (2.9%)	4 (28.6%)		2 (20.0%)	3 (7.9%)	
Maxillectomy	2 (4.2%)	2 (5.9%)	0 (0.0%)		0 (0.0%)	2 (5.3%)	
Maxillectomy with rhinectomy	2 (4.2%)	2 (5.9%)	0 (0.0%)		0 (0.0%)	2 (5.3%)	
Virtual surgical planning (VSP)	23 (47.9%)	16 (43.2%)	7 (63.6%)	$p = 0.24$ (χ^2)	9 (90.0%)	14 (36.8%)	**$p = 0.003$ (χ^2)**
Free flap type				$p = 0.42$ (χ^2)			$p = 0.10$ (χ^2)
Fibula	35 (72.9%)	25 (67.6%)	10 (90.9%)		10 (100.0%)	25 (65.8%)	
Osteocutaneous radial forearm (OCRF)	12 (25.0%)	11 (29.7%)	1 (9.1%)		0 (0.0%)	12 (31.6%)	
ALT	1 (2.1%)	1 (2.7%)	0 (0.0%)		0 (0.0%)	1 (2.6%)	
Case length (min)	482 ± 173	512 ± 161	381 ± 181	**$p = 0.02$ (t test)**	546 ± 162	465 ± 174	$p = 0.19$ (t test)
Length of stay (days)	10.0 ± 5.2	10.1 ± 5.3	9.7 ± 5.1	$p = 0.84$ (t test)	8.4 ± 3.0	10.4 ± 5.6	$p = 0.28$ (t test)
Duration of follow up (months)	16.0 ± 14.8	18.6 ± 15.7	6.9 ± 5.3	**$p = 0.02$ (χ^2)**	10.3 ± 8.1	17.4 ± 15.9	$p = 0.18$ (χ^2)
Adjuvant radiotherapy	26 (61.9%)	26 (74.3%)	0 (0.0%)	**$p < 0.00$ (χ^2)**	5 (71.4%)	21 (60.0%)	$p = 0.57$ (χ^2)
Time to radiotherapy (days)[a]		56.9 ± 21.8			49.4 ± 10.1	58.9 ± 23.8	$p = 0.40$ (t test)
Adjuvant chemotherapy	18 (45.0%)	17 (50.0%)	1 (16.7%)	$p = 0.13$ (χ^2)	5 (71.4%)	13 (39.4%)	$p = 0.12$ (χ^2)
Post-op HBOT	13 (27.7%)	8 (21.6%)	5 (50.0%)	**$p = 0.08$ (χ^2)**	7 (70.0%)	6 (16.2%)	**$p = 0.001$ (χ^2)**
Recurrence		10 (25.6%)			0 (0.0%)	10 (30.3%)	$p = 0.12$ (χ^2)
Adverse events	18 (37.5%)	8 (21.6%)	1 (9.1%)	$p = 0.26$ (χ^2)			$p = 0.73$ (χ^2)
Flap failure[b]	1 (2.1%)	1 (2.7%)	0 (0.0%)		0 (0.0%)	1 (2.6%)	
Hematoma/bleeding	1 (2.1%)	1 (2.7%)	0 (0.0%)		0 (0.0%)	1 (2.6%)	
Infection	12 (25.0%)	12 (32.4%)	0 (0.0%)		5 (50.0%)	7 (18.4%)	
Exposed hardware	5 (10.4%)	4 (10.8%)	1 (9.1%)		1 (10.0%)	4 (10.5%)	

Note: Bold values are statistically significant.

[a]Mean time to radiotherapy based on data available for 24 patients. In the implant group, 5 patients had malignancy for which the mean time to radiotherapy is reported.

[b] Flap failure occurred in a 74-year-old male with multiple comorbidities (hypertension, coronary artery disease status post percutaneous coronary intervention and CABG, chronic obstructive pulmonary disease, chronic kidney disease, deep venous thrombosis, carotid stenosis status post carotid endarterectomy, and transient ischemic attack) and Stage IVB metastatic disease. An additional patient had partial flap loss of the skin paddle only that was treated with a split thickness skin graft, and this was not included. Two patients required take backs to the operating room for anastomosis revisions, both of which were successful.

TABLE 3

Dental reconstruction characteristics and outcomes.

Dental reconstruction	Total (n = 10)	Malignancy (n = 5)	No malignancy (n = 5)	p value
Osteointegrated implants	10 (20.8%)	5 (13.5%)	5 (45.5%)	**p = 0.02 (χ^2)**
At time of flap recon	10 (20.8%)	5 (13.5%)	5 (45.5%)	
Delayed[a]	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Number of bone segments used (mean)	2.2 ± 0.6	2.4 ± 0.9	2 ± 0	p = 0.35 (t test)
Number of implants placed	4.2 ± 1.8	4.8 ± 2.0	3.6 ± 1.5	p = 0.32 (t test)
Method of placement				p = 0.53 (χ^2)
Free hand	5 (50.0%)	2 (40.0%)	3 (60.0%)	
Guided	5 (50.0%)	3 (60.0%)	2 (40.0%)	
Location of placement				p = 0.36 (χ^2)
Leg	7 (70.0%)	3 (60.0%)	4 (80.0%)	
Oral cavity	1 (10.0%)	0 (0.0%)	1 (20.0%)	
Back table	1 (10.0%)	1 (20.0%)	0 (0.0%)	
Vestibuloplasty/debulking	4 (40.0%)	1 (20.0%)	3 (60.0%)	p = 0.20 (χ^2)
Time to vestibuloplasty (months)	11 ± 6.7	21 ± 0	7.7 ± 0.6	
Implant complications[b]	3 (30.0%)	3 (60.0%)	0 (0.0%)	p = 0.17 (χ^2)
Temporary dental prosthesis received	2 (20.0%)	0 (0.0%)	2 (40.0%)	
Time to temporary prosthesis (months)	12 ± 4	0	12 ± 4	
Final dental prosthesis received[c]	3 (30.0%)	1 (20.0%)	2 (20.0%)	
Time to final prosthesis (months)	17.7 ± 12.4	32 ± 0	10.5 ± 0.7	

[a]One patient had four implants placed at the time of reconstruction with an additional two implants placed during a second stage procedure at a later date.

[b]One patient had osteoradionecrosis with hardware infection that required removal of hardware, after which the fibula shifted position inferiorly resulting in extrusion of one of the implants through the neck skin. Another had recurrent infections ultimately requiring hardware removal.

[c]Three patients received a final prosthesis. Of these, two never received a temporary prosthesis. Two patients had non-implant supported removal partial dentures. Five patients did not receive a prosthesis despite placement of osteointegrated implants at the time of initial surgery.