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Original Article

The dental implant survival rate in 18 patients with post-operation revolutionary jaw reconstruction using free fibular flap, dental implants, and overdentures

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KEYWORDS
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Overdenture

Abstract *Background/purpose:* This retrospective study assessed the risks and complications associated with dental implants after jaw surgery and radiotherapy for large defects, highlighting challenges for reconstructive surgeons and prosthetic dentists.
Materials and methods: From 2002 to 2008, National Taiwan University's Department of Maxillofacial Surgery used preoperative stereolithographic models and microvascular flaps for mandibular reconstruction in 18 patients with defects from ameloblastoma or advanced gingival cancer. They received free fibular flap grafts, followed by 46 osseointegrated dental implants. Patient outcomes, monitored for up to 60 months, were assessed through clinical and radiographic evaluations of implant success.
Results: The overall survival rate of dental implants following tumor surgery and radiotherapy was 84.8%. Seven implants failed due to peri-implantitis (3), tumor recurrence (2), and osteoradionecrosis (ORN) (2). The ameloblastoma group did not contribute to implant failure, with 4 implant failures in the stage III gingival cancer group, and 3 implant failures in the stage IV gingival cancer group.

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Conclusion: Following segmental mandibulectomy for mandible lesions, free fibular bone graft reconstruction restored mandible continuity, while subsequent dental implantation and overdenture fabrication restored occlusion and aesthetics for patients. Besides considering treatment strategies for ameloblastoma groups, similar approaches can be extended to oral cancer patients undergoing post-operative reconstruction. However, additional considerations (peri-implant soft tissue condition, tumor recurrence, ORN, etc.) are necessary for oral cancer patients predisposed to dental implant failure post-surgery.

Introduction

Large defects in the jaws and adjacent tissues following surgery pose a significant challenge for reconstructive surgeons and prosthetic dentists. Interdisciplinary cooperation among oral and maxillofacial surgeons, plastic surgeons, and prosthodontists is crucial. Such collaboration is vital for successful mandibular reconstruction, aiming to restore both function and aesthetics.[1] Titanium reconstruction plates are employed to reestablish mandibular continuity after segmental mandibulectomy, thereby enhancing the patient's facial contour.

The use of Medical Rapid Prototyping (MRP) techniques facilitates preoperative reconstruction plate fabrication by producing models of both the diseased mandible and the corresponding healthy mandible.[2] This application greatly facilitates the accuracy and efficiency of the surgery. Bone graft adaptation on the reconstruction plate provides a solid foundation for dental implant rehabilitation. Among the various options for mandibular reconstruction, the vascularized fibula free flap has become the preferred method due to its sufficient length, height, and plasticity to accommodate an implant-retained prosthesis.[3] Its advantages include improved structural support and aesthetic appearance, making it the gold standard in mandibular reconstruction.

Moreover, numerous studies have outlined treatment strategies and identified predisposing factors for implant failure in these patients. Factors such as radiotherapy,[4] the timing of implant placement (immediate or delayed)[5] the method of reconstruction (vascularized or non-vascularized bone graft[6] and the type of dental rehabilitation devices (overdenture or implant-supported prosthesis) are crucial considerations addressed in this study.[7]

The aim of this study was to assess the rehabilitation outcomes of 18 patients treated with a free fibula flap combined with delayed insertion of 46 dental implants. The focus includes the timing of dental rehabilitation following the free fibula flap procedure and an analysis of the reasons for implant failure. Through this retrospective study, we aim to share comprehensive experiences in mandibular reconstruction using a free fibula flap, followed by dental implantation and prosthetic fabrication, to aid peers in reference and research.

Materials and methods

This study presents our collective experience with implant-based dental rehabilitation of patients with mandible defects treated at the Department of Oral and Maxillofacial Surgery, National Taiwan University (Taipei, Taiwan) between July 2002 and September 2008. The study involved 18 patients and a total of 46 implants, all placed in grafted bone. Prosthetic dental rehabilitation was successfully completed for all subjects. Of the patients, 15 presented with malignancies, while the remaining 3 were diagnosed with ameloblastoma. Among the 15 lower gingival cancer patients, 12 were at stage III, and the remaining 3 were at stage IV. Patients' ages ranged from 33 to 58 years (mean: 45 $\pm$ 4.3 years), with 16 male patients and 2 female patients. In postoperative care for cancer patients, routine cancer follow-up visits were conducted every 2–4 weeks. This included an examination of the oral mucosa and regular panoramic X-rays for confirmation. Additionally, MRI tumor post-operation screenings were performed every six months to one year.

All patients underwent imaging studies (CT or MRI) before surgery, and prosthodontic consultation was sought for stereolithographic models. A protocol was implemented wherein stereolithographic models were created preoperatively for all patients undergoing mandibular reconstruction with microvascular flaps. Thus, 18 stereolithographic models were generated before segmental mandibulectomy. Titanium plates for fixation were chosen and preoperatively bent on the models (Fig. 1). Additionally, the reconstruction plates were intentionally bent inwardly by 5–10 mm to avoid a cross-bite occlusion of the neomandible (Fig. 2). The geometrical information from virtual mandibular resections and stereolithographic models facilitated communication with plastic surgeons for treatment planning.

All patients underwent surgery, including segmental mandibulectomy, reconstruction plate placement, free fibula flap reconstruction, and for the 3 stage IV patients, adjuvant radiotherapy. Pathological reports revealed either squamous cell carcinoma or ameloblastoma. Follow-up time ranged from 6 to 60 months (mean: 39 $\pm$ 7.3 months). All implants were inserted by the same surgeon. Following a further healing period of 6–9 months, interim dentures were fabricated for ameloblastoma patients

(Fig. 3), serving as transitional prostheses for adaptation and determining further implant sites. Surgical stent placement for implantation was based on patient satisfaction with the interim denture. Generally, in cancer patients without radiotherapy, interim dentures were fabricated until 12 months post-operation, allowing for follow-up of cancer recurrence status. Radiotherapy was administered to 3 stage IV cancer patients, with a total of 6 implants placed at least 18 months post-radiotherapy. None of our patients received hyperbaric oxygen treatment.

For all patients with free flaps composed of bone, muscle, and skin, the skin around the transmucosal portion of the implants was removed, and free mucosal grafts from the palate were transplanted to improve the soft tissue-to-implant interface during implant placement (Fig. 3). The completion time for overdentures (indicating near-total recovery of function and aesthetics) was at least 12 months for ameloblastoma patients, 16 months for non-radiotherapy cancer patients, and 24 months for radiotherapy cancer patients. The implant timetable is listed in Table 1.

Implant success rates were evaluated according to Albrektsson criteria[8] which include absence of mobility, absence of painful symptoms or paresthesia, absence of peri-implant radiolucency, and absence of progressive marginal bone loss. Implant success was determined based on clinical and panoramic findings (Fig. 4). Implants that loosened and subsequently dislodged from their original sites were considered failures.

Results

Out of a total of 46 implants, 7 experienced osseointegration failure, resulting in a global osseointegration success rate of 84.8%. The average observation period was 38 months (mean: 39 $\pm$ 7.3 months) from the time of ablative surgery. Of the 7 failure implants, 3 were lost in the mandible due to lack of osseointegration, and 3 were lost due to local cancer recurrence. The remaining 2 implants were lost due to osteoradionecrosis. However, the remaining 39 observable implants remained clinically stable (Table 1).

Among three patients who underwent malignant tumor resection and received radiotherapy with doses of 50—60 Gy over the tumor bed and lymph node chains. Implant placement was conducted 18 months after the last session of radiotherapy. However, half of these implants (3 out of 6) failed due to tumor recurrence (1 case) and osteoradionecrosis (2 cases), indicating a higher rate of implant failure in patients who underwent oral tumor resection combined with radiation therapy.

Apart from the six implants placed in patients treated with cancer surgery combined with radiation therapy, an additional 34 implants were placed in 12 patients who underwent cancer surgery only. Among these, 4 implants (11.7%) failed due to loosening (3 cases, with an average failure time of 13 months) and tumor recurrence (1 case, occurring 13 months after implant placement). These failures generally occurred between 11 and 15 months post-implantation.

In contrast, among the 6 implants positioned in 3 patients subjected to aggressive resection of ameloblastoma, no implant failures were observed.

Figure 1 Preoperatively, a stereolithographic model was used along with a reconstruction plate that was bent inward by 5—10 mm.

Discussion

The use of free vascularized fibula grafts was first reported in 1975 b y Taylor et al.[9] They successfully employed this graft to bridge a large posttraumatic defect in the contralateral tibia. Since then, the vascularized fibula flap has been widely utilized for reconstructing mandibular defects of varying lengths. The dimensions of the bone are typically suitable for accommodating endosteal implants, and the fibula provides bicortical support for these implants. Other advantages of the fibular bone include its ample length (20—26 cm), a relatively long vascular pedicle with large diameter vessels, good bone quality, and the ability to contour the bone with multiple osteotomies.[10,11] In addition to its benefits as a bone flap, the fibula can be harvested with a reliable, thin skin component perfused by septocutaneous vessels.[12] The skin island is highly mobile because it is isolated on the posterior crural septum only, making it advantageous during insetting procedures.

Contouring of the reconstruction plate that fixes the fibula is crucial for achieving correct alignment of the temporomandibular joints, optimal occlusion, and restoring mandible continuity to improve aesthetic outcomes. Ideally, the reconstruction plate should be adapted to the native mandible prior to segmental mandibulectomy. However, in cases where the soft tissue tumor bulges from or invades into the mandible, this technique may not be feasible. In such conditions, bone grafts and fixation plates may need to be reshaped during the operation through trial and error, often leading to time-consuming procedures.

In this study, we reconstructed stereolithographic models during the preoperative planning of complex mandibular reconstructions after tumor resections. We also employed the mirror-image technique to duplicate the premorbid form of the mandible. Preoperatively, titanium plates for fixation were selected and bent according to the premorbid model.

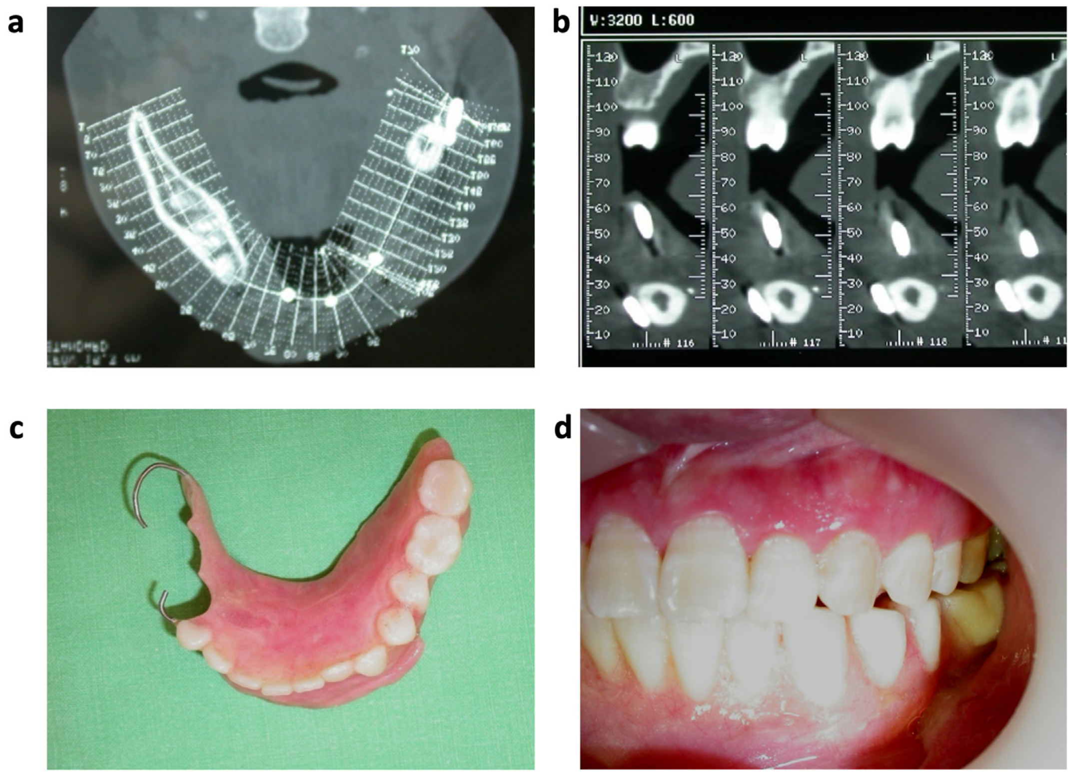

Figure 2 Pre-implantation design in a neo-mandible and an interim denture fabrication. (a) In the axial cone-beam CT prepared for implantation, the fibula bone was noted to be inward. (b) At the implant site corresponding to the neo-mandible at position #35, a non-crossbite occlusion is exhibited, (c, d) along with a treatment denture for an ameloblastoma patient six months post-operation.

The main drawback of using the fibula flap for mandible reconstruction is its relatively small height of 13 mm.[11] This poses a dilemma in restoring the contour of the lower border of the mandible for aesthetic purposes versus creating adequate alveolar height for osseointegrated dental implants. To address these issues, double-barreled constructs (Fig. 5) or positioning implants 1 cm above the inferior border of the mandible can be considered. However, these solutions mainly address achieving adequate alveolar height for osseointegrated dental implants. Furthermore, the reconstruction plate was intentionally bent inwardly by 5—10 mm to avoid a cross-bite position of the neomandible (Fig. 1). This discrepancy is camouflaged by de-epithelialized soft tissue to achieve optimal aesthetics.

While the vascularized fibula restores mandible continuity, the placement of osseointegrated teeth can almost completely restore function and form. The use of osseointegrated implants in patients with maxillofacial defects has been a common practice for the past several years.[13] Experiences with implant placement during mandible reconstruction (immediate implantation) and insertion several months post-operatively (deferred implantation) were discussed. Immediate implant placement reduces the total number of surgical procedures required for dental rehabilitation, allows easier access to the mandible, provides the best opportunity for obtaining optimal dental ridge relationship, and achieves a more rapid return to normal function.

Riediger[14] was the first author to place deferred implants in microsurgical flaps, while Urken et al.[15] pioneered immediate implant placement at the time of bone reconstruction. Schliephake et al.[16] based on more rigorous criteria, reported a mean cumulative survival rate of 56.5% at long term (10 years), with improved results in the case of deferred implants (67.1%) compared to immediate implants (36.2%). Immediate placement of implants reduces the total number of surgical procedures required for dental rehabilitation, allows easier access to the mandible, provides the best opportunity for obtaining optimal dental ridge relationship, and achieves a more rapid return to normal function. However, for patients who may receive post-operative radiotherapy, there is an increased risk of radiation-induced xerostomia and the possibility of developing osteoradionecrosis.[17] Additionally, successful osseointegration depends on viable bone cells for osteogenesis at the bone-to-implant interface. Bone grafts are considered "dead bone" until creeping substitution has taken place. Therefore, an adequate time is needed for creeping substitution to occur.[18] Another reason for deferring implant placement is that implant placement at the time of reconstruction is difficult and rarely satisfies the expectations of the prosthodontist.[19,20] In our study, we also deferred implant placement several months after fibula bone reconstruction.

Excessive thickness and mobility of the skin flap, and the lack of a vestibular sulcus in composite vascularized bone grafts for mandibular reconstruction, limit the usefulness of

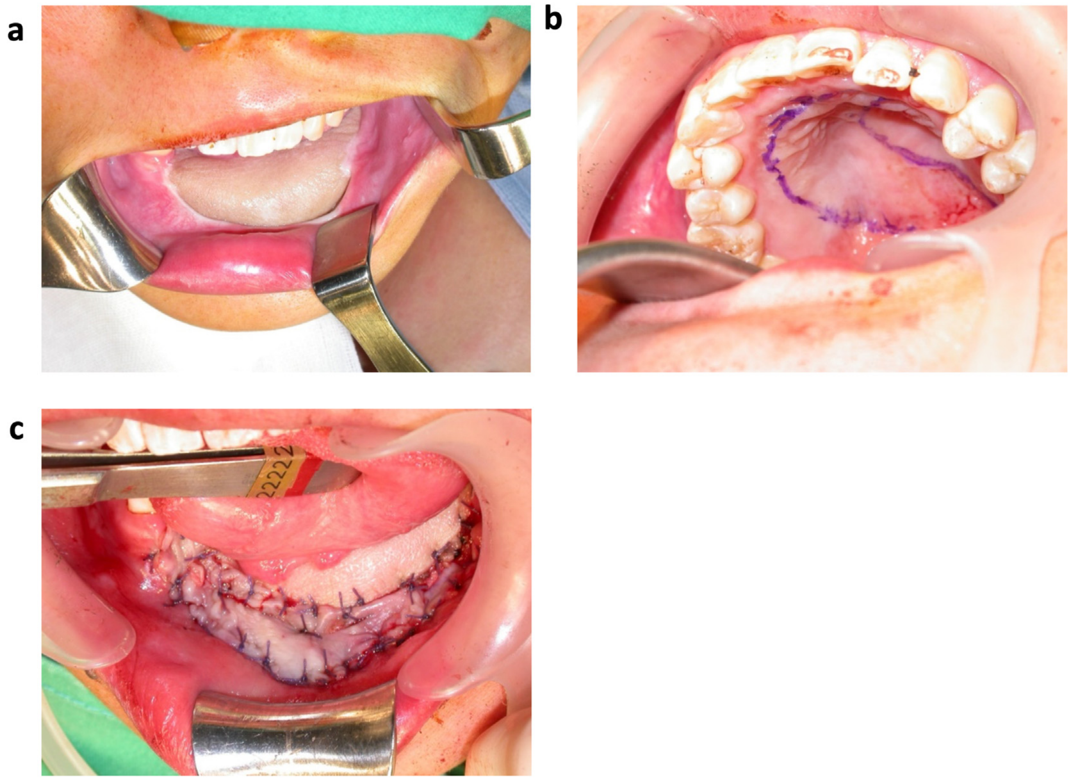

Figure 3 De-bulking surgery of vascularized fibula flap with palatal mucosal graft. (a) A bulky flap in the lower anterior region of a neo- mandible. (b) Demarcation of a palatal mucosal graft. (c) Replacing the bulky flap with a palatal mucosal graft caused.

Table 1 Timetable of the implants and failure pattern.

	Ameloblastoma (n = 3)	Gingiva cancer Stage III (n = 12)	Gingiva cancer Stage IV (n = 3)
Surgery	+	+	+
Radiotherapy	−	−	+
Treatment denture (months)	6—9	12	18—24 (post-R/T)
Dental CT palatal graft (months)	6—10	12—14	18∼28
Overdenture (months)	12∼16	16∼20	24∼30
Failure rate	0/6 (0%)	4/34 (11.7%)	3/6 (50%)

Abbreviations: CT, computed tomography. R/T: radiotherapy.

endosteal implants to support a prosthetic device. Palatal mucosal grafts can overcome this problem. Several studies have mentioned that the health or quality of the soft tissue surrounding an implant may be influenced by many factors. The presence of keratinizing mucosa surrounding an implant is thought to be a positive factor in maintaining soft-tissue health.[21—25] Implants surrounded by mobile soft tissue may often lead to inflammatory changes and pocket formation.[26—29] On the other hand, the keratinized tissue surrounding implant abutments tends to be less subject to peri-implant inflammation.[30,31] In our study, we used a technique to improve the soft tissue environment around endosteal implants by using palatal mucosal grafts to replace the skin flap. Soft tissue management in areas of implant rehabilitation may be performed before the surgical phase, after the surgery phase and before the prosthetic phase, or after completion of the prosthetic phase.[32] In our study, we performed the procedures under the second condition when implant insertion occurred simultaneously or after implant insertion. If marginal inflammation persisted around the abutment of the implant-supported denture, palatal gingival grafting was also performed to encourage marked gingival improvement.

In our series, the results of osseointegration and implant viability after loading have generally been good. Osseointegration failure (15.2%) is closely associated with three factors: radiation, implant loosening, and recurrent tumor. Failure of already rehabilitated implants almost always occurs in irradiated patients. There has been considerable controversy over the timing of implant placement in irradiated jaws. Kim et al.[33] recommended waiting for the irradiated bone until vascularization has partly recovered and neo-osteogenesis appears, usually within 3—6 months after radiotherapy. Jacobsson[34] suggested a minimum period of 9 months between irradiation and implant placement. Granstrom et al.[35] proposed that the success rate of implants in an irradiated zone depends, among other factors, on the waiting period before placement, which ranges from 6 to 18 months. Taylor and Worthington[36] consider 2 years to be a minimum waiting period.

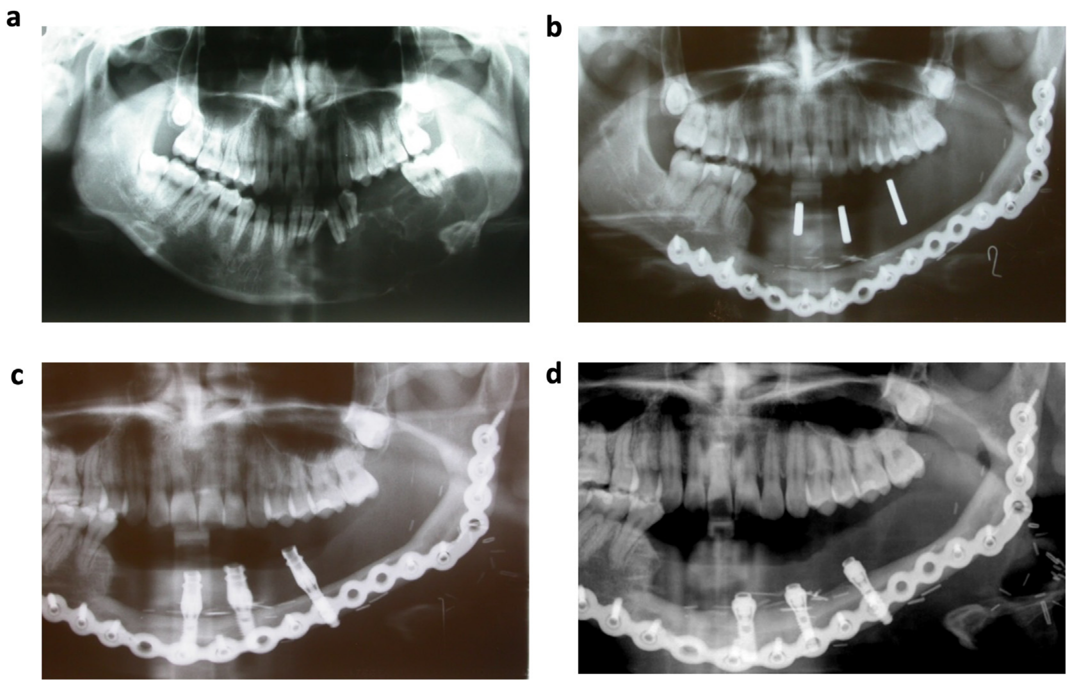

Figure 4 A radiograph displaying three osseointegrated implants in a lower left mandible following radical resection of ameloblastoma, with vascularized free fibular flap reconstruction. (a) Initial panoramic x-ray. (b) Six months post-operation, depicting the patient wearing a surgical stent equipped with three positional pins for implant preparation via cone-beam CT. (c) Three implants visible in the vascularized fibular flap on the left side of mandible. (d) Fifty-four months post-implantation, panoramic x-ray revealing comprehensive bone healing with no signs of peri-implant radiolucency.

In our study, the waiting period for implant placement was 18–24 months.

Nevertheless, Marx et al.[37] reported a continuous loss of capillaries over time after radiation therapy and advocated for surgery 1–6 months after radiation therapy to decrease the chances of osteoradionecrosis (ORN). ORN is one of the most problematic complications of radiotherapy, defined by Marx[38] as a metabolic and tissue failure caused by irradiation. Hypoxia, low cell count, and hypovascularity lead to tissue alteration, which can be exacerbated by traumatic aggression and infection. Based on the principles established by Marx,[39] hyperbaric oxygen therapy began to be used to induce neoangiogenesis and increase fibroblast activity, ensuring increased oxygen partial pressure in previously hypoxemic and ischemic irradiated areas. The universally accepted protocol comprises 30 sessions—20 before implantation and 10 after surgery—using hyperbaric oxygen at 100% concentration and 2.4 atm pressure, with a duration of 90 min per session. In 1998, Niimi et al.[40] described a series of 228 implants placed in irradiated maxillas in the United States and Japan. Their results showed a 98% success rate for irradiated mandibles subjected to hyperbaric oxygen therapy. In the case of the upper jaw, the success rate was 72%. Similar figures were reported by Ali et al.[41] with a 60% success rate in the upper maxilla and a 100% success rate in the lower jaw.

The literature thus concludes that hyperbaric oxygen appears to be essential for ensuring upper maxillary success rates approaching those obtained in the mandible[40,42] and implants can be placed in irradiated jawbone by following a careful protocol, even in patients who have not received hyperbaric oxygen therapy.[40] The management of ORN was complex and multidisciplinary, aiming to reduce symptoms, promote healing, and restore function. The approach to managing osteoradionecrosis depended on the severity of the condition, the specific needs of the patient, and the available resources. Treatment plans needed to be individualized, often requiring collaboration between oncologists, surgeons, radiologists, dentists, and other healthcare professionals. When ORN did occur, key strategies in managing osteoradionecrosis began with a preference for conservative management, which included administering antibiotics to combat secondary infections and using analgesics for pain control. Hyperbaric Oxygen (HBO) therapy played a crucial role in enhancing tissue oxygenation and promoting the healing of affected bone areas. Additionally, the use of pharmacological agents such as pentoxifylline and tocopherol helped reduce inflammation and supported tissue recovery. This integrated approach not only addressed ORN effectively when it arose but also focused on preventing the onset of ORN. Those literature review findings align with our clinical conclusions. In our patient cohort, none received hyperbaric oxygen therapy, yet the overall success rate of implant osteointegration exceeded 80%.

Results from this study, despite the limited number of patients and the short follow-up, showed that both bone grafts and revascularized flaps are reliable means for the rehabilitation of resected patients with osseointegrated implants and implant-borne prostheses.

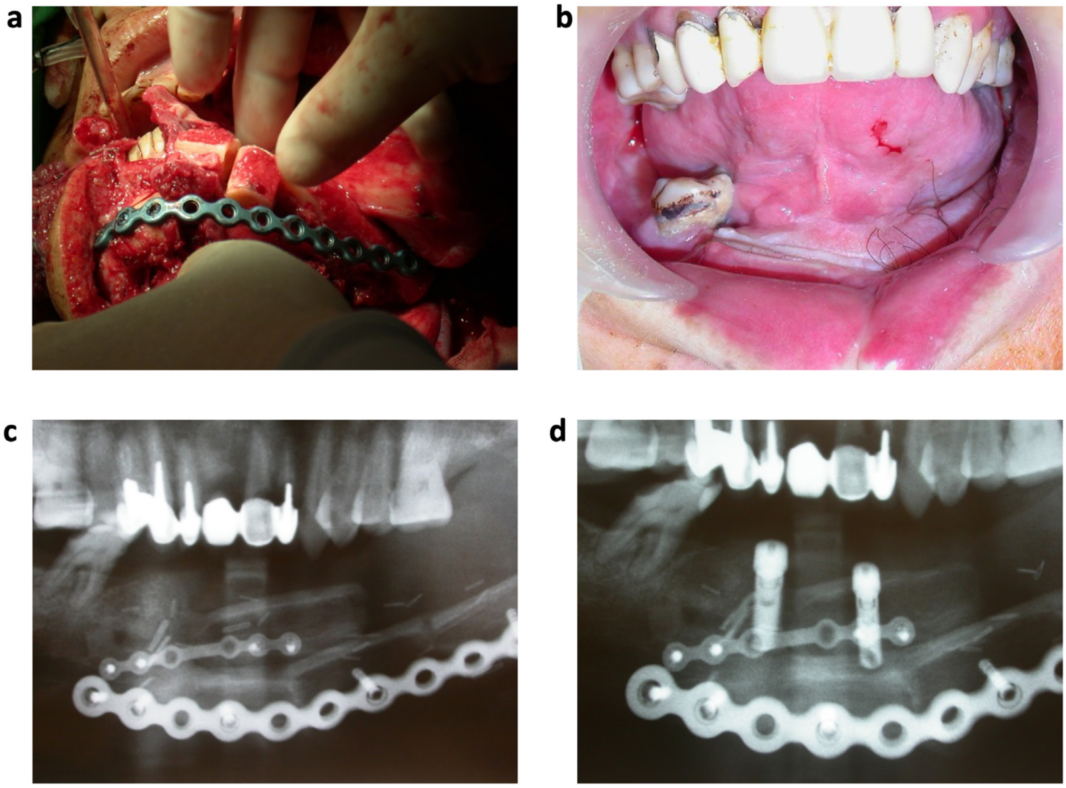

Figure 5 Double-barrel vascularized free fibula in mandibular reconstruction. (a) The process begins with the insetting of a double-barrel vascularized free fibula after tumor resection. (b) Following the wound healing, a less bulky flap is noted, indicating successful initial recovery. (c) Radiographic imaging reveals the structure of the double-barrel fibula bone. (d) After a 12-month observation period, osseointegrated implants are successfully placed in the double-barrel neo-mandible, completing the reconstruction process.

Declaration of competing interest

The authors have stated that there are no conflicts of interest related to this study.

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