International Journal Dental and Medical Sciences Research
Volume 6, Issue 4, July-Aug 2024 pp 365-374 www.ijdmsrjournal.com ISSN: 2582-6018

Revolutionizing Jaw Reconstruction: A Comprehensive Review of Free fibula Grafts in Maxillofacial Surgery

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Submitted: 15-08-2024 Accepted: 25-08-2024

ABSTRACT: Mandibular reconstruction using the fibula free-flap technique marks a significant advancement in oral and maxillofacial surgery. This review assesses the impact of postoperative rehabilitation on patients' quality of life, highlighting the necessity of comprehensive rehabilitation for optimizing functional recovery, enhancing aesthetics, minimizing complications, and improving overall well-being. It underscores the importance of tailored rehabilitation protocols and ongoing support to address both physical and emotional aspects of recovery. Mandibular reconstruction has advanced significantly with improvements in surgical techniques and three-dimensional technology. Although nonvascularized bone grafting remains in use, vascularised flaps offer distinct advantages, such as immediate reconstruction, the potential for dental implants, and the ability to repair composite defects involving both soft tissue and bone. This review explores current vascularised techniques for mandibular reconstruction, emphasizing a defect-based approach focused on comprehensive rehabilitation to guide surgeons in selecting the most suitable reconstruction options.

Keywords: Hemi-mandibulectomy, Mandibular reconstruction, Fibula graft, Postoperative Complications, Clinical Outcomes, Functional Recovery, Aesthetic Rehabilitation

I. INTRODUCTION:

Facial defects generally fall into two principal categories: soft tissue defects and composite defects, which involve reconstructing both bone and soft tissue. The demand for addressing these defects has driven the advancement of multiple tissue transfer techniques.[1]The free fibula flap is a reliable and strong vascularized bone graft required for the reconstruction of mandibular defects. The main issues in jaw reconstruction include the correction of jaw height and contour to reestablish dental occlusion and facial symmetry.[2]Many methods have been used for mandibular reconstruction, and avascular bone grafting after tumor resection has been performed for over a century.[3] Walter first described the use of fibula grafting in 1911, and Hidalgo introduced the free fibula flap for mandibular reconstruction in 1989.[4]This flap is now considered the gold standard for jaw reconstruction. The fibula free flap offers multiple advantages for reconstruction, including ample bone length, ease of dissection, and minimal donor-site morbidity. Its long pedicle with large-caliber vessels and vascular independence from the recipient site make it ideal for irradiated or poorly vascularized areas. (Figure 1)

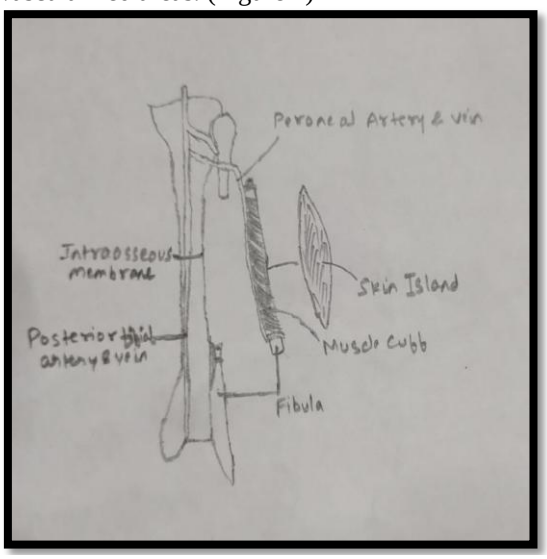

Figure 1: Vascular fibula flap

International Journal Dental and Medical Sciences Research
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Additionally, the fibula free flap provides extensive bicortical bone for dental implants and a versatile cutaneous unit, enhancing both bony and soft tissue reconstruction.[5]The fibula is bicortical bone with good inherent properties for future osseointegration.The fibular flap was first described by Taylor et al. in 1975, with the lateral approach being validated, and later in 1979, Gilbert introduced the external approach.[6] The fibular osteocutaneous flap was described by Chen and Yan in 1983 and its anatomy by Wei et al in1986 and Carret al in 1988.[7]The harvested flap should include the skin paddle, fibula bone, associated skin perforators, and peroneal vessels (Figure 2).[8]

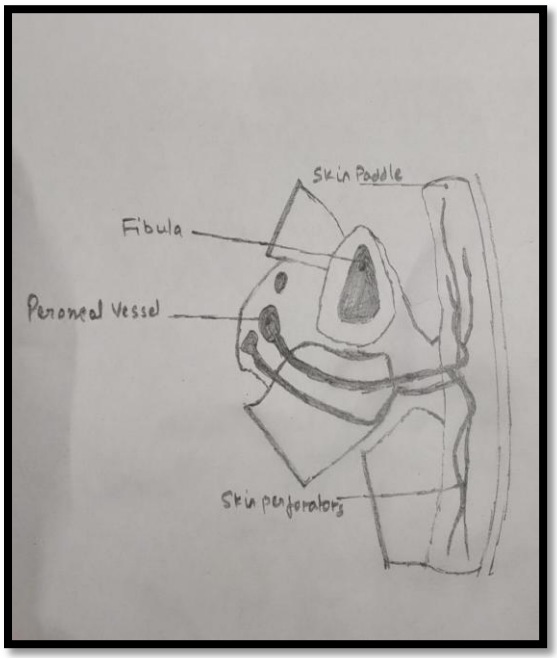

Figure 2: Design of flap

Bones up to 22 cm in length can be harvested and shaped.[9] The flap can be carried with a thin, hairless paddle on a removable diaphragm that can be used inside or outside the oral cavity.[10] If there are many perforating vessels in the septum, the skin will be divided and used on both sides of the bone. Its biggest disadvantage is that the blood is not stable on the skin.[11]The frequency of donor sites is very low in Goodacre et al. 1990.[12]Two surgical teams can operate simultaneously with the patient lying on his back, one on the legs and the other on the head and neck. The fibular flap was harvested from a lateral approach under a tourniquet.[13] The skin flap is marked on the posterolateral aspect of the fibula and is concentrated near its midpoint.[14]The anterior margin is reflected to expose the posterior intermuscular septum.[15]If the artery is not visible, the posterior aspect of the flap should be elevated to include the peroneal artery and the branch entering the soleus.[16]The fibula is exposed and sectioned with a Gigli saw.[17]The dissection continues around the bone, preserving the muscle tissue to prevent periosteal bleeding. Identify and preserve the peroneal artery and venous companions.[18]Because the vascular pedicle of the flap is short, the vein is usually used to attach the flap to the vein in the neck.[19]This prevents vascular kinking because the vascular pedicle is usually parallel to the bone and the arteries in the neck are usually unaffected by previous surgery or radiation therapy.[20]A section of the long saphenous vein was collected from the thigh. The artery was divided into two at the saphenofemoral eye above the junction of the lateral and middle femoral veins, and one of these was collected.[21]This allows for the subsequent end-to-end anastomosis of the two flap veins with the vein graft.[22]The artery is placed in the neck and anastomosed end-to-end to a branch of the contra lateral external carotid artery or end-to-side to the external carotid artery itself.[23] The venous end is anastomosed end-to-side with the contra lateral internal carotid artery.[24]A temporary arteriovenous fistula or venous graft loop was created by Taylor, 1983; a malleable template is created.[25]Initially, a tangential image of the patient's mandible is used.[26] The surgeon must be carefully cut and adjusted to accommodate the removed bone. This difference in level would cause unnecessary problems in fixation and shaping.[27]The specimen is then transferred to the leg and several complete osteotomies are made on the fibula using a fine ball or oscillating saw.[28] These segments are carefully lengthened, leaving the endoperiosteal space intact. Cut the bones predictably and accurately and bend them to the correct shape. The central osteotomy is fixed with a mini plate by Champy et al. 1978.[29]Irrigate the fibula with saline and carefully preserves the blood vessels throughout the procedure. The flap is transferred to the mandibular defect and held firmly in place using additional micro bone plates.This eliminates the need for physical attachment.[30]To shorten the ischemic transplantation time; these plates should be shaped and mounted to the recipient bone before transplantation.[31]The flap artery and flap vein are then anastomosed to the artery graft ring after appropriate horizontal division. If so, the second flap vein anastomoses with a branch of the long saphenous vein.[32]

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II. DISCUSSION:

Radiological assessment for mandibular reconstruction often involves panoramic radiographs, which are limited in detail and are used primarily due to patients' lack of social security coverage. Maxillofacial computed tomography (CT) scans offer more detailed information for planning mandibular interventions. Initially, both bilateral lower extremity CT angiography and facial CT scans are employed to create a virtual surgical plan, aiding in precise surgical planning.[33] The plan includes instructions for creating fibular cuts, mandibular resections, and reconstruction plates. The decision to use the ipsilateral or contra lateral fibula depends on various factors, such as the location of the defect, the direction of the flap, and the recipient's vasculature.[34]When the intraoral skin needs to be anastomosed to the ipsilateral carotid artery, the ipsilateral fibula is resected with the skin layer behind the myenteric membrane.[35]During the operation, the midline is first taken from the fibular head to the lateral malleolus and divided into three parts.[36]Then, a skin perforator is placed approximately 1 cm after the intersection of the middle and third lines using the Doppler device.[37]For this purpose, the skin is created around the determined perforators and the tourniquet is increased to 250 mm Hg.[38] The anterior skin is incised and subcutaneous dissection is performed to elevate and stabilize the anterior skin flap.[39] The deep fascia is incised over the peroneus brevis muscle and subfascial dissection is performed posterior to the diaphragm to expose the perforating artery.[40] While preserving the perforators, isolate the skin and separate the peroneus longus and peroneus brevis muscles of the fibula, leaving a 1 x 2 mm muscle cuff of the cannon bone.[41]The anterior septum of the foot is identified and the anterior chamber muscle is removed from the fibula.[42] Proximal and distal osteotomies of the fibula are performed using a right-angle clamp and a sagittal view placed behind the fibula.[43] Care should be taken to leave a 7 cm gap at the tip of the fibula to protect the peroneal artery and stabilize the joint. The interosseous membrane is divided from distal to proximal and the fibula is retracted to ensure accuracy. The peroneal vascular bundle is identified, ligated distally, and dissected upward. The deep posterior muscle is separated from the fibula and the fibular resection is extended to the trifurcation point.[44]The pedicle is separated from the proximal fibula using a periosteal scraper and reconstructed by lengthening the pedicle as part of the bone.[45] The fibular guide plate was fixed with unicortical screws, and 80% of the osteotomy was performed in the sagittal plane.Remove the surgical guide, hold the pedicle, and complete the remaining osteotomy. Before cutting the fibular pedicle, the fibular flap segment was fixed to a 2.7-mm locking reconstruction plate using unicortical locking screws.[46]A cutting guide is used to make a hole in the lower jaw before removing the tumor. After the pedicle is separated, the flap is transferred to the mandible and fixed to the remaining mandible with locking screws.[47]A micro vascular anastomosis is then performed to the ipsilateral carotid artery, and a skin graft is placed on the mucosal surface to cover the fibula and the reconstructed plate.[48] To complete the surgery, interpalatal correction is performed using interpalatal posts and heavy tape to reduce the force during reconstruction.[49] In the past, many different bone grafts have been used to reconstruct the mandible, either free grafts or attached to the muscle pedicle. The latter has questionable blood, but in the last decade, avascular transplants have gained popularity because of their reliable blood. This not only promotes more rapid healing and bone healing, but also reduces the risk of infection, especially when local tissue has been exposed to radiation.[50] The most commonly used free flap for intraoral reconstruction is the forearm flap by Yang et al. and Soutar et al in 1981.[51] Many authors have documented problems with the use of this flap, including Soutar et al in 1983 and Timmons et al in 1986.[52]These include limited radius, extension and supination, lack of sensation on the dorsum of the hand, and a broad forehead. Jones and OâBrien reported in 1985 a case of hand ischemia requiring rapid repair of the radial artery and vein.[53] Two advantages of the fibular flap are the length of available vascularised bone and the limited donor area.[54]A length of at least 22 centimetres of bone is available to reconstruct the mandible, along with a radius of 8 centimetres.The bone features a robust periosteal blood supply and includes muscle fibers that can be carefully divided by surgical osteotomies and secured with microplates after being shaped Champy et al. in 1978.[55]The advantages of this procedure have been previously described by Frame et al. in 1987.[56] The technique is simple and precise, minimizing the need for extraneous steps. The skin functions as both a protective layer for the underlying bone and a supportive covering during the reconstruction. Careful attention is necessary when dissecting the fascia, but the trapezoidal D-shaped vascular configuration in the fascial area allows the flap to be divided into two parts.[57]A Doppler ultrasound can be utilized to identify the transected artery prior

to surgery, as observed by Yoshimura et al. in 1984.[58] The idea first introduced by PontCn in 1981 and further detailed in 1982, suggested that two to five perforating vessels pass through the septum and connect to the axial artery, forming the primary vascular structure of the fasciocutaneous area.[59]An exhaustive anatomical analysis of the flap by Wei et al. in 1986 confirmed Barclay's conclusions but noted the absence of perforating vessels in the septum.[60]Therefore, when the maximum is reached, it is safer to remove the anterior part of the skin without exposing the perforating artery in the septum. If this nerve cannot be found, the musculocutaneous muscle of the soleus muscle is included to control the incision.[61]A recent study by Carr et al. in 1988 study showed that longer flaps may be more successful.[62] Septal perforators usually occur in the middle third of the extremity; unlike the radius, almost the entire length of the fibula can be used without severe pain to the patient.[63]A recent study by Goodacre et al. found that in 1990, in three patients who underwent fibula graft rehabilitation, only one of 10 patients who underwent surgery to remove an 18-centimeter portion of the fibula without adequate plantar support from the hallux did not survive.[64] Fibula graft jaw reconstruction is an effective method of long-bone repair that provides both aesthetic and functional benefits to the patient. Jaw loss can damage the bone, resulting in permanent jaw loss. Mandibulectomy reconstruction after mandible can be performed at any age, regardless of gender and social status. These tumors frequently affect young people, who represent a portion of the population.[65] Ameloblastoma has a slight male predilection and is more common in fourth and fifth decade of life. Developing countries have high rates of cancer, mainly due to inadequate treatment, inappropriate and expensive treatment, and delays in seeking care that may result from reliance on conventional and nonsurgical therapies.[66]S. Atala et al. reported that 71 percent of the patients were male.[67]Hongyang Ma et al. studied a total of 74 patients, comprising 55 males and 19 females according to their reports.[68]Dental symptoms are sometimes symptoms of some tumours in the mandible and maxilla. Radiological examination should be done before tooth extraction to find the underlying disease. Some patients complain of mild pain and swelling of the jaw. The swelling will continue until it merges with the jaw and the skin cover looks good. The swelling of the jaw and the deformity of the face are the complaints of the patient. Benign tumours can take years or years to develop because their symptoms are few. Since ameloblastoma is a tumour that can recur locally, it is necessary to wait for a while after surgical removal. The extent of facial deformity is described in the literature.[69] Research has identified a variety of causes.[70]According to studies by Maben et al., 65% of the cases were squamous cell carcinoma, 5% were spindle cell carcinoma, 15% were ameloblastoma, 10% were ossifying fibroma, and 5% were odontogenic keratocyst.[71]Preoperative vascular examination of the pelvic extremities is critical before preparing a fibular flap due to the risk of atherosclerosis, which can disqualify the fibula for use. Symptoms such as leg swelling, limited motion, and difficulty in pulse detection highlight the need for thorough evaluation.[72] Diagnostic tools like arteriography, Doppler ultrasound, and vascular scans are essential to assess the health of the blood vessels and the extent of vascularization.[73]After the tumor is surgically resected, mandibular reconstruction using a fibula graft can be delayed and performed functionally without requiring standard fibular osteotomy and guide cutting. While fibula grafts are not yet widely utilized in mandibular reconstruction, the free fibula flap is anticipated to become the gold standard. This technique not only provides robust bone grafting but also offers the flexibility of including soft tissue, such as muscle and skin, thanks to its vascular supply from the facial artery, external carotid artery, and other nearby vessels. Preparation for mandibular reconstruction using a free fibula flap has improved since Hidalgo first described it in 1989.[74]These advancements will shorten the operative time needed for fibula flap creation. Virtual surgical planning enables the surgeon to visualize the defect and conduct a mandibular resection. This system also allows for preoperative fibular osteotomy and free flap placement, and facilitates the creation of complete cutting models and intraoperative surgical instructions. However, this approach is costly and requires a lengthy operating time. Due to the high expenses, surgeons have explored methods to reduce costs and preparation time.[75] Neeb et al. proposed that developing mandibular reconstruction models would benefit many patients.[76]To achieve a balanced mandibular arch, utilizing three segments effectively accommodates the consistent angle between the mandibular and symphyseal regions. Post-surgery, patients were advised to remove dentures, as extractions are more cost-effective and simpler than dental implants. Although dental implants provide a durable, long-term solution, their higher cost and the need for meticulous preparation and patient cooperation can limit their feasibility for middle-income patients.Prosthetic rehabilitation remains a viable

option for those who have undergone jaw reconstruction, ensuring optimal coordination and preservation of the temporomandibular joint. Implants can be placed either during or immediately following surgery, enhancing both functionality and aesthetic outcomes. This approach not only promotes effective reconstruction but also supports long-term oral health and patient satisfaction.[77] Cuellar et al. observed that restorative dental implant treatment was delayed in all patients. Huang et al. documented 47 endosseous implants in 13 patients.[78] Robert J. Allen et al. found that immediate dental implants are a safe procedure, with no short-term complications and no delay in starting radiation therapy.[79] Patientswho receive immediate dental treatment post-surgery are more likely to maintain excellent oral hygiene, highlighting the importance of timely intervention. Effective collaboration among healthcare providers and thorough education in dental implantology are crucial for enhancing postoperative compliance and the success of these procedures.Patient evaluations reveal high satisfaction with mouth opening, dental articulation, chewing, and swallowing functions. While some speech difficulties were reported, patients were largely pleased with their aesthetic results. However, one female patient expressed discomfort due to visible scars, underscoring the need for sensitive post-surgical support.[80]The study's findings align with existing literature: 97% of patients resumed oral feeding, 89% spoke clearly, and 86% rated their appearance as good or fair.[81] Overall, oromandibular reconstruction using a free bone flap effectively restores oral health, with over 80% of patients satisfied with their speech and appearance. This approach not only improves function and aesthetics but also enhances overall patient well-being and quality of life.[82]

Types of Mandibular Defects and Their Subunits: Many attempts have been made to classify mandibular defects, but the optimal classification remains elusive. Many surgeons follow the classification by Urken et al., which was described in 1991 and divides the mandible based on functional, aesthetic, and anatomical considerations.[83]This classification divides the mandible into four sections: condyles, ramus, body, and symphysis. The symphysis is defined as the part of the mandible between the canines, the body extends from the canines to the ramus, the ramus defect extends from the angle to the subcondylar region, and the condylar defect includes the condylar neck and the temporomandibular joint. Brown et al. conducted a comprehensive literature review and proposed a new classification for mandibular tumors.[84] This classification categorizes defects into groups I to IV based on the angle of the canines and mandible, with a "c" subclassification for condylar involvement.Higher classifications correspond to increased size and complexity of the mandibular anatomy requiring reconstruction. These classifications allow the surgeon to optimally plan the reconstruction using either of the previously described classifications. In a typical lateral defect (posterior body and ramus of the mandible, or Class I), the defect is usually straight without curvature. These defects involve minimal muscle attachment, which can lead to disturbances in function, such as speech and swallowing disorders. A straight bony reconstruction is usually sufficient, and osteotomy of the free flap is often not necessary. It is important to ensure that the bone is in harmony with the maxillary teeth to facilitate future dental implant reconstruction, which should be part of the overall reconstructive plan.For defects extending to the condyle after tumor resection (ascending ramus/condylar process, Class II or IIc), a decision must be made as to whether the condyle can be plated without violating the joint space. If condylar plating would violate the joint space, complete condylar resection may be necessary. If the joint space is compromised and the condylar fossa is exposed, care must be taken to ensure that the hardware does not approach the condylar region, as this could lead to erosion of the base of the skull and perforation into the middle cranial fossa. Optimal reconstruction of the fossa/condylar complex and the interpositional graft is complex and beyond the scope of this section.[85]For anterior mandibular defects, particularly symphyseal and Class III defects, effective reconstruction is crucial for both functional and aesthetic outcomes. The symphysis, an essential area for muscle attachment and oral function, is best reconstructed using a single osteotomized bone segment due to the increased risk of vascular compromise with multiple smaller segments. The use of advanced pre-surgical planning technologies, such as computerized simulations, enhances the precision of these reconstructions, ensuring better outcomes in terms of both lip support and overall aesthetics. For larger, long-span defects (Class IV) extending from one angle of the mandible to the other, reconstruction becomes more complex.[86]The fibula free flap, first described by Taylor et al. in 1975, is a preferred option due to its substantial bone length (20–26 cm), which is critical for achieving the necessary span and structural support.[87] This flap's advantages include its reliable vascular supply from the peroneal artery and its adaptability for

implant placement, which supports long-term dental rehabilitation. The flexibility of the fibula flap allows it to be used as an osseous, osteocutaneous, or osteoseptocutaneous flap, and it can be harvested concurrently with other procedures due to its distal donor site location.Despite its benefits, the fibula flap comes with challenges, such as donor site complications including scarring and potential functional issues with the flexor hallucis longus.[88] Innovations like the tunneling technique and implantable Doppler probes have improved the efficiency and monitoring of flap viability, while noninvasive techniques such as near-infrared spectroscopy and indocyanine green angiography offer advanced methods for assessing blood flow and flap health.[89]Postoperative care is critical, involving strategies to prevent complications and ensure optimal recovery. Nutritional support via nasogastric, nasojejunal, or gastrostomy tubes, along with meticulous management of thromboembolism, antibiotics, and fluid balance, are essential for successful outcomes. Oral feeding typically resumes after about 5 days, with a progressive diet starting at 2 weeks and regular foods reintroduced by 6 weeks to prevent malunion or nonunion.[90]State-of-the-art advancements, such as Virtual Surgical Planning (VSP), represent a leap forward in reconstructive surgery. VSP integrates computer-assisted planning, 3D printing for custom implants and guides, and precise surgical execution to improve accuracy and reduce operative time. Although VSP involves significant costs, its ability to streamline procedures and enhance surgical precision offers substantial benefits.[91] The innovative Jaw in a Day procedure exemplifies progress in dental rehabilitation, enabling simultaneous mandibular reconstruction and dental implant placement, which not only accelerates restoration but also significantly enhances patient quality of life. While long-term success rates of implants in this context are still under evaluation, the immediate benefits in terms of functional and psychological well-being are well-documented.[92]

III. CONCLUSION:

Mandibular reconstruction using the fibula free flap is a versatile and effective technique that offers significant benefits in terms of bone length, vascularized tissue, and functional outcomes. Advances in surgical planning and postoperative care continue to improve the success and efficiency of this procedure, making it a gold standard for complex mandibular defects.

Financial support and sponsorship Nil
Conflicts of interest There are no conflicts of interest

REFERENCES

1. Verhelst PJ, Dons F, Van Bever PJ, Schoenaers J, Nanhekhan L, Politis C. Fibula Free Flap in Head and Neck Reconstruction: Identifying Risk Factors for Flap Failure and Analysis of Postoperative Complications in a Low Volume Setting. Craniomaxillofac Trauma Reconstr. 2019; 12(3):183-192.
2. Maeher G, Michael SF, Seung Jun S et al. Immediate microvascular maxillofacial reconstruction and dental rehabilitation: protocol, case report, and literature review. PlastAesthetRes.2021; 8:37.
3. Chang YM, Wallace CG, Hsu YM et al. Outcome of osseointegrated dental implants in double-barrel and vertically distracted fibula osteoseptocutaneous free flaps for segmental mandibular defect reconstruction. PlastReconstr Surg. 2021; 134(5):1033–1043.
4. 4.Hidalgo DA, Pusic AL. Free-flap mandibular reconstruction: a 10-year follow-up study. PlastReconstr Surg. 2002; 110:438–449.
5. Chaine A, Pitak-Arnnop P, Hivelin M, Dhanuthai K, Bertrand JC, Bertolus C. Postoperative complications of fibular free flaps in mandibular reconstruction: an analysis of 25 consecutive cases. Oral Surg Oral Med Oral Pathol Oral RadiolEndod. 2009; 108(4):488-95.
6. Taylor GI, Miller GD, Ham FJ. The free vascularized bone graft. Aclinical extension of microvascular techniques. PlastReconstrSurg. 1975; 55(5):533–544.
7. Schrag C, Chang YM, Tsai CY, Wei FC. Complete rehabilitation ofthe mandible following segmental resection. J Surg Oncol. 2006; 94 (6):538–545.
8. Maurer P, Eckert AW, Kriwalsky MS, Schubert J. Scope and limitations of methods of mandibular reconstruction: a long-term follow-up. Br J Oral Maxillofac Surg. 2010; 48(2): 100–104.
9. Delacure M. reconstruction of the mandible. Indian J Plast Surg. 2007; 40(supplement): 28-34.
10. Peled M, El-Naaj IA, Lipin Y, Ardekian L. The use of free fibula flap for functional mandibular reconstruction. J Oral Maxillofac Surg. 2005; 63(2): 220-24.

11. Biglioli F, Pedrazzoli M, Autelitano L, Colletti G, Brusati R. The free fibula flap for treating benign mandibular lesions. Minerva Stomatol. 2007; 56(6): 349-58.
12. Sukato DC, Hammer D, Wang W et al. Experience with "jaw in a day" technique. J Craniofac Surg. 2020; 31(5):1212–1217.
13. Goh BT, Lee S, Tideman H, Stoelinga Paul JW. Mandibular reconstruction in adults: a review. Int J Oral Maxillofac Surg. 2008; 37(7): 597–605.
14. Okay D, Al Shetawi AH, Moubayed SP, et al. Worldwide ten-year systematic review of treatment trends in fibula free flap for mandibular reconstruction. J Oral Maxillofac Surg. 2016; 74:2526–2531.
15. Hidalgo DA. Aesthetic improvements in free-flap mandible reconstruction. PlastReconstr Surg. 1991; 88(4): 574-85.
16. Ozalp T, Masquelet AC, Begue TC. Septocutaneous perforators of the peroneal artery relative to the fibula: anatomical basis of the use of pedicled fasciocutaneous flap. SurgRadiol Anat. 2006; 28(1):54-8.
17. Sajid MAH, Warraich RA, Abid H, Ehsan-ul-Haq M, Shah KL, Khan Z. Reconstruction of mandibular defects with autogenous bone grafts: a review of 30 cases. J Ayub Med Coll Abbottabad. 2011; 23(3): 82-5.
18. Szpindor E. Evaluation of the usefulness of autogenic bone grafts in reconstruction of the mandible. Ann Acad Med Stetin. 1995; 41: 155–69.
19. Kim MR, Donoff RB. Critical analysis of mandibular reconstruction using AO reconstruction plates. J Oral Maxillofac Surg. 1992; 50(11): 1152–57.
20. Thoma A, Levis C, Young JE. Oromandibular reconstruction after cancer resection. Clin Plastic Surg. 2005; 32(3): 361–375.
21. Riaz N, Warraich R. Reconstruction of Mandible by Free Fibular Flap. J Coll PhySurg Pak. 2010; 20(11):723-27.
22. Pieptu D, Gogalniceanu D, Getu N, Grosu O, Popescu S, Costan V. Mandibular reconstruction using the free fibula osteocutaneous flap. TMJ. 2005; 55(1): 43-8.
23. Nicolic Z, Jeremic J, Milosavjevic R. Use of free microvascular flaps in the management of the head and neck defects. Vojnsanit Pregl. 2006; 63(8): 713-20.
24. Lin C-H, Kudva A. Simultaneous reconstruction of mandibular and maxillary defects using the single free fibular osseocutaneous flap: case series and review of the literature. Ann Plast Surg. 2021; 86:428-433.
25. Runyan CM, Sharma V, Staffenberg DA et al. Jaw in a day: state of the art in maxillary reconstruction. J Craniofac Surg.2016; 27(8):2101–2104.
26. Urken ML, Weinberg H, Vickery C, Buchbinder D, Lawson W, BillerHF. Oromandibular reconstruction using microvascular composite free flaps. Report of 71 cases and a new classification schemefor bony, soft-tissue, and neurologic defects. Arch OtolaryngolHead Neck Surg. 1991; 117(7):733–744.
27. Knitschke M, Sonnabend S, Bäcker C. Partial and total flap failure after fibula free flap in head and neck reconstructive surgery: retrospective analysis of 180 flaps over 19 years. Cancers. 2021; 13(4): 865.
28. Marx RE, Cillo JE Jr, Broumand V, Ulloa JJ. Outcome analysis ofmandibular condylar replacements in tumor and trauma reconstruction: a prospective analysis of 131 cases with long-termfollow-up. J Oral Maxillofac Surg. 2008; 66(12):2515–2523.
29. Serra J, Paloma V, Mesa F. The vascularized fibula graft in mandibular reconstruction. J. Oral MaxillofacSurg Off. 1991; 49:244-250.
30. Kumar BP, Ventakesh V, Kumar KAJ, Yadav BY, Mohan SR. Mandibular Reconstruction: Overview J Maxillofac Oral Surg. 2016; 15(4): 425–41.
31. Shen Y, Guo XH, Sun J, Li J, Shi J, Huang W et al. Double-barrel vascularised fibula graft in mandibular reconstruction: a 10-year experience with an algorithm. J PlastReconstrAesthet Surg. 2013; 66(3):364-71.
32. Qiu S, Kang Y, Ding M et al. Mandibular reconstruction with the iliac flap under the guidance of a series of digital surgical guides. J Craniofac Surg.2021; 32(5):1777–1779.
33. Rodby KA, Turin S, Jacobs RJ, et al. Advances in oncologic head andneck reconstruction: systematic review and future considerations of virtual surgical planning and computer aided design/ computer aided modeling. J PlastReconstrAesthet Surg. 2014; 67 (9):1171–1185.
34. Hsu LC, O'Brien JP, Yau AC, Hodgson AR. Valgus deformity of theankle in children with fibular pseudarthrosis. Results of

treatment by bone-grafting of the fibula. J Bone Joint Surg Am. 1974; 56 (3):503–510.
35. Rosenthal E, Carroll W, Dobbs M, Wax M, Peters G. Simplifying head and neck micro-vascular reconstruction. Head Neck. 2004; 26(11): 930-36.
36. Disa JJ, Cordeiro PG. Mandible reconstruction with microvascularsurgery. Semin Surg Oncol. 2000; 19(3):226–234.
37. Chang TY, Lee YC, Lin YC, et al. Implantable Doppler probes forpostoperatively monitoring free flaps: efficacy. A systematic review and meta-analysis. PlastReconstrSurg Glob Open. 2016; 4(11):e1099.
38. Mofikoya B, Belie O, Ugburo A. Clinical outcome of microsurgical free flap procedures in Lagos, Nigeria. Nigeria Journal of Plastic Surgery. 2020; 16:45-50.
39. Pellini R, Pichi B, Marchesi P, Cristalli G, Deganello A, Spriano G. External monitor for buried free flaps in head and neck reconstructions. Acta Otorhinolaryngol Ital. 2006; 26(1):1–6
40. Takasu H, Hashikawa K, Nomura T, Sakakibara S, Osaki T, TerashiH. A novel method of noninvasive monitoring of free flaps with near-infrared spectroscopy. Eplasty. 2017; 17:e37.
41. Hitier M, Cracowski JL, Hamou C, Righini C, Bettega G. Indocyaninegreen fluorescence angiography for free flap monitoring: a pilot study. J Craniomaxillofac Surg. 2016; 44(11):1833–1841.
42. Shan X, Han D, Ge Y et al. Clinical outcomes of keratinized mucosa augmentation in jaws reconstructed with fibula or iliac bone flaps. Int J Oral Maxillofac Surg.2022; 51(7):949–956.
43. Han HH, Kim HY, Lee JY. The pros and cons of computer-aidedsurgery for segmental mandibular reconstruction after oncological surgery. Arch Craniofac Surg. 2017; 18(3):149–154.
44. Halim AS, Yusof I. Composite vascularised osteocutaneous fibulaand sural nerve graft for severe open tibial fracture–functionaloutcome at one year: a case report. J OrthopSurg (Hong Kong). 2004; 12 (1):110–113.
45. Modabber A, Legros C, Rana M, Gerressen M, Riediger D, Ghassemi A. Evaluation of computer-assisted jaw reconstruction with free vascularized fibular flap compared to conventional surgery: a clinical pilot study. Int J Med Robot. 2012; 8(2):215–220.
46. Edwards SP. Computer-assisted craniomaxillofacial surgery. OralMaxillofacSurg Clin North Am. 2010; 22(1):117–134.
47. Markiewicz MR, Miloro M. The evolution of microvascular andmicroneurosurgical maxillofacial reconstruction. J Oral Maxillofac Surg. 2018; 76(4):687–699.
48. Silverman DA, Przylecki WH, Arganbright JM, et al. Evaluation of bone length and number of osteotomies utilizing the osteocutaneous radial forearm free flap for mandible reconstruction: an 8- year review of complications and flap survival. Head Neck. 2016; 38 (3):434–438.
49. Ferreira JJ, Zagalo CM, Oliveira ML, Correia AM, Reis AR: Mandible reconstruction: History, state of the art and persistent problems. ProsthetOrthot Int. 2015, 39:182-9.
50. Seikaly H, Idris S, Chuka R et al. The Alberta reconstructive technique: an occlusion-driven and digitally based jaw reconstruction. Laryngoscope. 2019; 129(Suppl 4):S1–S14.
51. Patel A, Harrison P, Cheng A, Bray B, and Bell RB: Fibular reconstruction of the maxilla and mandible with immediate implant-supported prosthetic rehabilitation: jaw in a day. OralMaxillofacSurg Clin North Am. 2019, 31:369-86.
52. Lonie S, Herle P, Paddle A, Pradhan N, Birch T, Shayan R: Mandibular reconstruction: meta-analysis of iliacversus fibula-free flaps. ANZ J Surg. 2016, 86:337-42.
53. Wang KH, Inman JC, Hayden RE: Modern concepts in mandibular reconstruction in oral and oropharyngealcancer. Curr OpinOtolaryngol Head Neck Surg. 2011, 19:119-24.
54. Bolzoni A, Mapelli A, Baj A, Sidequersky FV, Giannì AB, Sforza C: Evaluation of three-dimensionalmandibular movements after reconstruction with free fibula flap. Acta Otorhinolaryngol Ital. 2015, 35:371- 8.
55. Lin CH, Kudva A: Simultaneous reconstruction of mandibular and maxillary defects using the single freefibular osseocutaneous flap: case series and review of the literature. Ann Plast Surg. 2021, 86:428-33.
56. Bolzoni AR, Pollice A, Nuti M, Baj A, Rossi DS, Beltramini GA: Clinical and functional outcomes of cad/cammandibular reconstruction with free fibular flap

comparing traditional versus micro-invasive intraoralsurgical approaches. J BiolRegulHomeost Agents. 2020, 34:175-84.
57. Okay D, Al Shetawi AH, Moubayed SP, Mourad M, Buchbinder D, Urken ML: Worldwide 10-year systematic review of treatment trends in fibula free flap for mandibular reconstruction. J Oral Maxillofac Surg. 2016, 74:2526-31.
58. Wijbenga JG, Schepers RH, Werker PM, Witjes MJ, Dijkstra PU: A systematic review of functional outcome and quality of life following reconstruction of maxillofacial defects using vascularized free fibula flaps and dental rehabilitation reveals poor data quality. J Plast ReconstrAesthet Surg. 2016, 69:1024-36.
59. Ou Q, Wu P, Zhou Z, Pan D, Tang JY: Complication of osteo reconstruction by utilizing free vascularized fibular bone graft. BMC Surg. 2020, 20:216.
60. Hartman EH, Spauwen PH, Jansen JA: Donor-site complications in vascularized bone flap surgery. J InvestSurg. 2002, 15:185-97.
61. Anne-Gaëlle B, Samuel S, Julie B, Renaud L, Pierre B: Dental implant placement after mandibularreconstruction by microvascular free fibula flap: current knowledge and remaining questions. Oral Oncol. 2011, 47:1099-104.
62. Pitak-Arnnop P, Hemprich A, Dhanuthai K, Pausch NC: Fibular flap for mandibular reconstruction: are there old tricks for an old dog?. Rev StomatolChirMaxillofacChirOrale. 2013, 114:15-8.
63. Markey J, Knott PD, Fritz MA, Seth R: Recent advances in head and neck free tissue transfer. Curr OpinOtolaryngol Head Neck Surg. 2015, 23:297-301.
64. Ong A, Williams F, Tokarz E, Shokri T, Hammer D, Ducic Y: Jaw in a day: immediate dental rehabilitationduring fibula reconstruction of the mandible. Facial Plast Surg. 2021, 37:722-7.
65. Gangwani P, Almana M, Barmak B, Kolokythas A: What is the success of implants placed in fibula flap? A systematic review and meta-analysis. J Oral Maxillofac Res. 2022, 13:e3.
66. Lee M, Chin RY, Eslick GD, Sritharan N, Paramaesvaran S: Outcomes of microvascular free flapreconstruction for mandibular osteoradionecrosis: a systematic review. J Craniomaxillofac Surg. 2015,43:2026-33.
67. Hwang L, Natividad EM, Ellis M. Fibula flap harvest: How leg selection impacts inset for mandible defects. Microsurgery. 2017; 37:459–460.
68. Qaisi M, Kolodney H, Swedenburg G et a. Fibula jaw in a day: state of the art in maxillofacial reconstruction. J Oral Maxillofac Surg.2016; 74(6):1284 e1281-1284 e1215.
69. Balaji SM. Total reconstruction of mandible by transport distraction after complete resection for benign and malignanattumors. Indian J Dent Res. 2016; 27(2): 205-12.
70. Okoturo E, Osasuyi A, Opaleye O. Vascularised fibula flaps for mandibular reconstruction: an institutional audit. Ann Med Health Sci Res. 2017; 7:46-51.
71. Lonie S, Herle P, Paddle A. Mandibular reconstruction: metaanalysisof iliac- versus fibula-free flaps. ANZ J Surg. 2016; 86:337-342.
72. Schusterman M, Reece G, Miller M. The osteocutaneous free fibula flap:is the skin paddle reliable?.PlastReconstr Surg. 1992; 90:787-793.
73. Semplicini A, Vindigni V, Giatsidis G. Padova HospitaleOnlus. Report of a 15-year experience in surgical and medical assistance in developing countries. Ann Plast Surg. 2013; 71:6-9.
74. Hidalgo DA. Fibula free flap: A new method of mandible reconstruction. PlastReconstr Surg. 1989; 84(1): 71-8.
75. Zhu H, Zhang L, Cai Z et al. Dental implant rehabilitation after jaw reconstruction assisted by virtual surgical planning. Int J Oral Maxillofac Implants.2019; 34(5):1223–1230.
76. Patel SY, Kim DD, Ghali GE: Maxillofacial reconstruction using vascularized fibula free flaps and endosseousimplants. Oral MaxillofacSurg Clin North Am. 2019, 31:259-84.
77. Frodel JL Jr, Funk GF, Capper DT et al. Osseointegrated implants: a comparative study of bone thickness in four vascularized bone flaps. PlastReconstr Surg. 1993; 92(3):449–455 discussion 456-448.
78. Zhu WY, Su YX, Pow EHN et al. “Three-in-one” patient-specific surgical guides for simultaneous dental implants in fibula flap jaw reconstruction: a prospective case series. Clin Implant Dent Relat Res.2021; 23(1):43–53.

79. Panchal H, Shamsunder MG, Petrovic I et al. Dental implant survival in vascularized bone flaps: a systematic review and meta-analysis. PlastReconstr Surg. 2020; 146(3):637–64.
80. Woods B, Schenberg M, Chandu A. A comparison of immediate and delayed dental implant placement in head and neck surgery patients. J Oral Maxillofac Surg. 2019; 77(6):1156–1164.
81. Grewal M, Forman MS, Song SJ, Eisig S, Friedman J, Troob S. Immediate microvascular maxillofacial reconstruction and dental rehabilitation: protocol, case report, and literature review. PlastAesthet Res. 2021; 8:37.
82. Fernandes RP, Yetzer JG. Reconstruction of acquired oromandibulardefects. Oral MaxillofacSurg Clin North . 2013; 25(02):241–249.
83. Urken ML, Buchbinder D, Costantino PD, et al. Oromandibularreconstruction using microvascular composite flaps: report of210 cases. Arch Otolaryngol Head Neck Surg. 1998; 124(01):46–55.
84. Brown JS, Barry C, Ho M, Shaw R. A new classification formandibular defects after oncological resection. Lancet Oncol. 2016; 17(1):e23–e30.
85. Kang YF, Lv XM, Qiu SY et al. Virtual surgical planning of deep circumflex iliac artery flap for midface reconstruction. Front Oncol.2021; 11:718146.
86. Tang CL, Mahoney JL, MckeeMD, Richards RR, Louie B. Donor site morbidity following vascularized fibular grafting. Microsurgery. 2019; 18(3): 383–386.
87. Chang YM, Wei FC. Fibula jaw-in-a-day with minimal computer-aided design and manufacturing: maximizing efficiency, cost-effectiveness, intraoperative flexibility, and quality. PlastReconstr Surg. 2021; 147(2):476–479.
88. Wallace CG, Chang YM, Tsai CY, Wei FC: Harnessing the potential of the free fibula osteoseptocutaneousflap in mandible reconstruction. PlastReconstr Surg. 2010, 125:305-14.
89. Roumanas ED, Garrett N, Blackwell KE et al. Masticatory and swallowing threshold performances with conventional and implant-supported prostheses after mandibular fibula free-flap reconstruction. J Prosthet Dent. 2006; 96(4):289–297.
90. Müller-Richter U, Betz C, Hartmann S, Brands RC. Nutritionmanagement for head and neck cancer patients improves clinicaloutcome and survival. Nutr Res. 2017; 48:1–8.
91. Ren W, Gao L, Li S, et al. Virtual planning and 3D printing modeling for mandibular reconstruction with fibula free flap. Med Oral Patol Oral Cir Bucal. 2018; 23:e359–e366.
92. Levine JP, Bae JS, Soares M, et al. Jaw in a day: total maxillofacialreconstruction using digital technology. PlastReconstr Surg. 2013; 131(6):1386-1391.