Ref: Ro Med J. 2023;70(4)
DOI: 10.37897/RMJ.2023.4.10

Comprehensive analysis of fibula free flap reconstruction: A retrospective study on limb defects and vascular considerations

Iulia Muraru[1], Dragos Zamfirescu[1], Dragos Muraru[1,2], Andreea Grosu-Bularda[3,4], Cristian Sorin Hariga[3,4], Ioan Lascar[3,4]

[1]Zetta Hospital, Bucharest, Romania
[2]Clinic of Plastic Surgery, "Dr. Carol Davila" Central Military University Emergency Hospital, Bucharest, Romania
[3]Clinic of Plastic Surgery, Aesthetic and Reconstructive Microsurgery, Clinical Emergency Hospital Bucharest, Romania
[4]"Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

ABSTRACT

The clinical applications of the fibula flap for reconstructing bone defects in the limbs have been widely studied. This study aims to investigate the use of the fibula flap in the treatment of bone defects resulting from trauma, infections, or oncological pathology. Additionally, the study focuses on analyzing preoperative experiences, including imaging and intraoperative aspects, to optimize preoperative planning. The study includes a retrospective analysis of adult patients who underwent surgical treatment for extensive bone defects from 2014 to 2020. Demographic data, surgical interventions, and postoperative complications were collected. Specific anatomical elements of the fibula flap, such as vascularization and dimensions, were also studied. The findings of this study provide valuable insights into the clinical applications and optimization of the fibula flap for reconstructive surgery.

Keywords: fibula free flap, limb reconstructive surgery, bone reconstruction

INTRODUCTION

The reconstruction of extensive bone defects, particularly in the limbs and mandibular region, has long been a challenging endeavor in reconstructive surgery. The advent of the fibula free flap has revolutionized this field, offering a versatile and reliable solution for such complex reconstructions. Introduced by Taylor et al. in 1975, the fibula free flap has become a preferred method due to its ample bone length, consistent vascular pedicle, and the possibility of incorporating a skin paddle for soft tissue reconstruction [1]. Its anatomical features, including the bone's size, shape, and biomechanical strength, make it an ideal choice for structural and functional restoration, especially in load-bearing areas like the lower limb [2]. The technique's evolution has been marked by an increasing understanding of its vascular anatomy, crucial for flap viability and surgical success. Studies have emphasized the importance of the peroneal artery and its perforators, which supply the skin paddle, making the flap versatile for composite tissue defects [3]. However, the intricacies of microvascular surgery, including the variability in vascular anatomy and potential for donor site morbidity, present significant challenges. These complexities underscore the need for meticulous preoperative planning, often involving advanced imaging techniques like CT angiography, to map out the vascular territory and enable precise flap design [4]. Despite its widespread application and proven efficacy, the use of the fibula free flap in limb reconstruction demands continuous scrutiny. Studies have shown varying rates of success and complications, influenced by factors such as the defect's etiology, patient comorbidities, and surgical technique variations [3]. This underscores the necessity for ongoing research to refine surgical techniques, enhance patient selection criteria, and optimize outcomes. The current study aims to contribute to this body of knowledge by presenting a retrospec-

Corresponding author:
Iulia Muraru
E-mail: iuliamurarumd@gmail.com

Article History:
Received: 7 December 2023
Accepted: 20 December 2023

tive analysis of fibula free flap reconstructions, focusing on clinical applications, anatomical considerations, and postoperative outcomes.

OBJECTIVES

The aim of this study was to investigate the clinical applications of the fibula flap for reconstructing bone defects in the limbs, resulting from trauma, infections, or oncological pathology. It also focused on analyzing preoperative experiences – imaging and intraoperative aspects, of the vascularization of the fibula flap that can be extremely useful in optimizing preoperative planning.

MATERIALS AND METHODS

A retrospective study was conducted on adult patients who were presented with extensive bone defects of the limbs and received surgical treatment for this pathology from 2014 to 2020. The inclusion criterion for the study group was the use of the free transferred fibula flap as an elective therapeutic method. Demographic data were collected on age, gender, comorbidities, etiology and location of the bone defect, type of surgical intervention performed, and postoperative complications. Specific anatomical elements of the fibula flap, such as the length of the fibula, dimensions of the skin island, the distance between the fibular head and the emergence of the anterior tibial artery and peroneal artery, the number of perforators, and their distribution along the calf, were also studied.

The variables used in this analysis were largely quantitative parameters. They were analyzed using Microsoft Excel and the SPSS statistics program. For the parameters or variables used in this study, extreme values, mean and standard deviation, coefficient of variation, standard error, and the hypothesis of normality were checked, both by assessing the existence of symmetry using the median and by using various normality tests (Shapiro-Wilk). The Chi-square test was used to determine if the null hypotheses were true (p-value = statistically significant if $p<0.05$).

RESULTS

Our study group comprised 14 patients, who underwent reconstruction of a limb bone defect with a free transferred fibula flap (Table 1). Of these, 12 patients were male, and the rest female. The average age of the patients was 41 years, ranging between 18 and 62 years. A proportion of 35% of patients had comorbidities such as dyslipidemia, obesity, and hypertension, and 21.5% of the patients were smokers.

TABLE 1. Frequency distribution - qualitative data

	Frequency	%
Gender		
male	2	14%
female	12	86%
Comorbidities		
yes	5	35%
no	9	65%
Smokers		
yes	3	21,5%
no	11	78,5%
Localization		
aseptic necrosis of the femoral head	3	21,5%
femur	3	21,5%
tibia	6	42%
humerus	1	7%
radius	1	7%
Etiology		
trauma	9	65%
idiopathic	3	21,5%
benign tumor excision	2	14,5%
Type of FFF		
osteocutaneous	11	78,5%
osteocutaneous – double barrel	2	14,5%

Most of the bone defects were localized in the lower limb (86%), with a predominance of defects at the level of the tibia. The study group also included two patients with defects in the upper limb, one presenting a bone defect of the humerus, and the other at the radius level (Figures 1-3).

The etiology of the bone defects was mostly post-traumatic (9 cases), 3 idiopathic, and 2 following the resection of benign tumor formations (giant cell tumor). With one exception, where a bony fibula flap was used, the reconstruction of bone defects was performed with osteocutaneous fibula flaps.

The harvesting of the fibula flap was performed in equal proportions from the contralateral or ipsilateral pelvic limb.

Based on imaging investigations – angio-CT, correlated with clinical elements identified intraoperatively, it was possible to establish the distance from the fibular head at which the emergence of the anterior tibial, posterior tibial, and peroneal arteries is present. This was extremely important in preoperative planning; the proximal osteotomy was performed so that the dissection of the peroneal pedicle could be carried out with ease. On average, the emergence of the peroneal artery occurred at 6.45 cm from the proximal epiphysis of the fibula.

The dimensions of the skin islands were variable, with an average of ~ 24cm^2 - 7×4 cm. In most cases, very large skin islands were not necessary, so a width of maximum 3.5 cm was preferred to be able to close the donor area primarily (Table 2).

FIGURE 1. Preoperatory clinical aspect of a forearm with radius defect

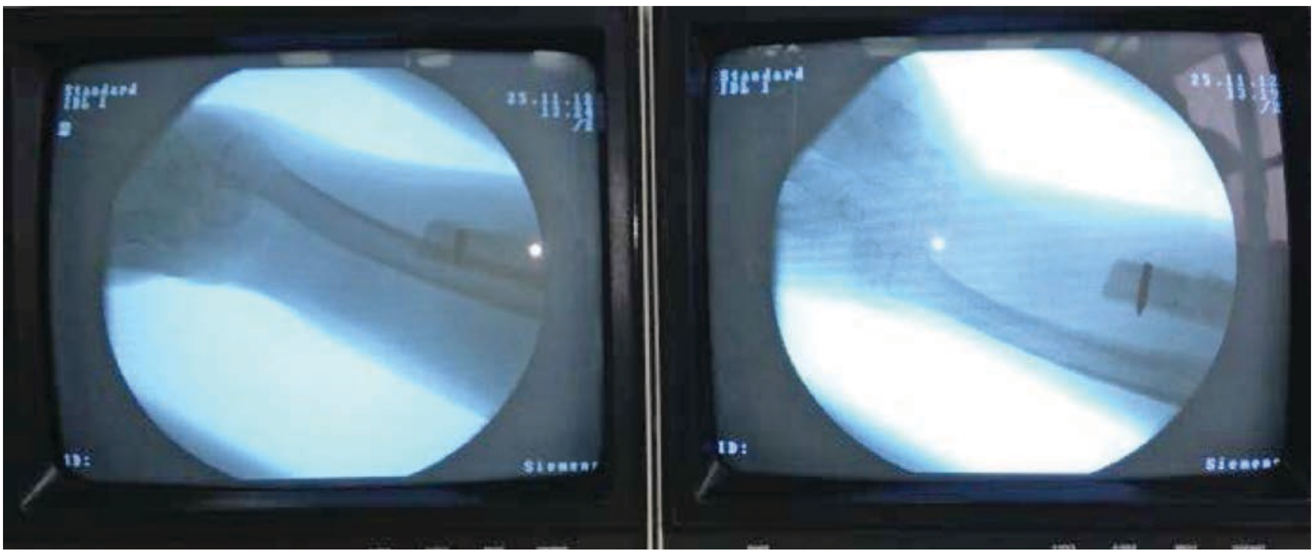

FIGURE 2. Preoperatory radiological aspect of a forearm with radius defect (AP view and profile)

TABLE 2. Vascularization - emergence of anterior, posterior tibial and peroneal arteries and dimensions of cutaneous islets

	min	max	m	sd	md	sk	k	S-W
Anterior tibial artery emergence	26	42	32.36	4.86	32.0	0.805	-.007	.88*
Peroneal artery emergence	58	75	64.50	5.33	63.0	0.59	-0.67	.92
Skin islet (cm²)	12	40	24	11.95	25.5	-0.32	-0.58	.95*

Note: m – arithmetic mean, sd – standard deviation, md – median value, sk – asymmetry coefficient, vaulting coefficient, S-W – value of the Shapiro-Wilk normality test

Also, musculocutaneous, and fasciocutaneous perforators of the peroneal artery were identified imaging-wise. Some of these were used to raise a skin island in cases where the fibula flap used for reconstructing defects was osteocutaneous. Perforator-based flaps were used in 13 of the patients, representing 92.8%. Two perforators were used in those cases.

Most frequently the perforators were found in the distal half of the calf, at an average distance of 10.3 cm, respectively 13.9 cm from the distal end of the fibula. Using imaging investigations (angio-CT), 2 perforators were identified in each patient. The average length of the fibula was 39 cm (Table 3).

FIGURE 3. Postoperative radiological aspect of the reconstructed radius (AP view and profile)

TABLE 3. The distribution of perforators in the calf and the length of the fibula according to measurements made with angio-CTs

Nr crt	Fibula distal extremity	1st perforator (mm)	2nd perforator (mm)	Number of perforators	Fibula length (mm)
1	0	109	142	2	385
2	0	111	138	2	413
3	0	127	169	2	398
4	0	122	165	2	388
5	0	114	152	2	392
6	0	143	182	2	396
7	0	113	152	2	405
8	0	116	150	2	393
9	0	84	130	2	356
10	0	84	136	2	348
11	0	105	132	2	388
12	0	115	137	2	411
13	0	133	160	2	403
14	0	118	150	2	386
	Average	103,85	139,64	2	390,14

TABLE 4. Length of the vascularized bone graft utilized

	min	max	m	sd	md	sk	k	S-W
Length of utilized bone graft	90	210	135	40.91	120.0	0.68	-0.88	.88*

Note: m – arithmetic mean, sd – standard deviation, md – median value, sk – asymmetry coefficient, vaulting coefficient, S-W – value of the Shapiro-Wilk normality test

The average length of vascularized bone graft utilized was between 9 and 21 cm, with an average length of 13.5 cm (Table 4).

The distribution analysis along the calf was performed based on the values obtained from the ratio between the distance from the perforator to the distal fibular end, and the total fibular length. The distal third of the calf is up to 0.33, distal half up to 0.5, the middle third is up to 0.67.

TABLE 5. Distribution of perforators along the calf and where they occur most frequently

Rank of perforator	n	min	max	m	sd
1st perforator	14	0.207	0.36	0.26	0.037
2nd perforator	14	0.33	0.76	0.36	0.042

Note: m – arithmetic mean, sd – standard deviation

From the results presented in the previous table, it is observed that for the first perforator, the maximum distance is in the middle third of the calf (max=0.36), and the mean distance is in the distal third of the calf (m=0.26) (Table 5).

The most common recipient vessels for anastomoses are the anterior tibial artery (42.8%) (Table 6), respectively, the anterior tibial vein (42.8%) (Table 7).

TABLE 6. Recipient artery

Recipient artery	Frequency	%
Deep femoral artery	2	14.3
Lateral femoral circumflex artery	3	21.4
Popliteal artery	1	7.4
Anterior tibial artery	6	42.8
Brachial artery	1	7.4
Radial artery	1	7.4

TABLE 7. Recipient vein

Recipient vein	Frequency	%
	2	
Lateral femoral circumflex vein	3	21.4
Popliteal vein	1	7.4
Anterior tibial vein	6	42.8
Basilic vein	1	7.4
Cephalic vein	1	7.4

DISCUSSION

The fibula free flap represents a pivotal advancement in the management of complex long bone defects. The vascularized bony or composite fibula flap shows efficacy in replacing segments of long bones compromised by oncological resections, traumatic injuries, or congenital malformations. The fibula, being a non-weight-bearing bone, offers a unique combination of structural integrity and vascular versatility, making it an ideal candidate for reconstructive procedures involving the femur, tibia, and humerus [5-8].

Most of our patients had post-traumatic defects, specifically 9 cases, and only 2 cases were represented by benign tumor pathology. In post-traumatic pathology, it is necessary to adhere to strict principles, involving aggressive debridement of devitalized tissues, ensuring adequate vascularization of the affected segment, and subsequently applying a reconstructive approach that addresses both skeletal defects and composite soft tissue defects. In trauma cases, a collaborative ortho-plastic approach is highly recommended. As established by Godina and widely regarded as a reconstructive principle, it is advised that soft tissue coverage for open extremity fractures be conducted within the first 72 hours following the traumatic event [9]. However, with the introduction of most recent technologies such as negative pressure wound therapy, flap coverage can be strategically delayed until the patient achieves stable systemic conditions. This approach allows for optimal timing of reconstructive surgery, ensuring the patient is in the best possible state for recovery and healing [10].

The free vascularized fibula flap is considered the premier option for vascularized bone grafting in the treatment of segmental long bone defects following trauma [11].

Also, free fibula flap stands as a workhorse flap within the therapeutic arsenal for limb reconstruction following the orthopedic resection of oncological long bones, in both adults and children. It showcases a high rate of bone healing, enables early ambulation, ensures good functionality, and maintains a low rate of complications. Additionally, it supports the continuation of adjuvant oncologic treatments needed in such patients [6,12,13].

Reconstruction after extensive bone tumors resection was described using a mix of allografts and free vascularized autologous fibula flaps, based on the technique first described by Capanna. This combined approach provides immediate mechanical stability and over time, the vascularized fibular grafts integrated with the allografts, forming fully biological and vascularized units [14,15].

The average length of the harvested fibular segment is in line with previous studies, being of an adequate size for the proposed reconstructions. Thus, the length of the fibula varied between 34.8 and 43.1 cm, with an average of about 39 cm. The length of the fibula segment used varied between 9 and 21 cm, with an average of 13.5 cm +/- 4.9 cm.

In a significant proportion of cases - 13 (92.85%) - the osteocutaneous fibula flap was used. This type of flap is generally used for covering soft tissue defects, but in most of these cases, the skin island was raised as a clinical indicator for postoperative monitoring of vascular perfusion.

Most frequently, the perforators in our study are encountered at the junction of the middle third with the distal third of the calf, which confirms studies in specialized literature. Thus, 16 perforators (57.14%) were identified in the distal third of the calf, near the junction with the middle third and 12 perforators (42.86%) were identified in the middle third.

Compared to various studies in literature up to now, the number of perforators from the peroneal artery identified in the calf for our study was generally lower, at only 2 perforators. However, it should be mentioned that the identification of perforators was mixed, clinical and imaging, and imaging-wise, perforators with a diameter of less than 0.3 mm could not be identified. Nonetheless, studies have shown that the accuracy rate in identifying perforators with angio-CT is extremely high, with very low rates of false positives and negatives [16]. Thus, Cho et al. identified an average of 3.58 +/- 0.71 perforators, Yu et al. identified an average of 2.52 perforators [17, 18]. In 2012, Iorio et al. published a detailed analysis of the specialty literature at that time related to perforators of the peroneal artery, from which he selected 6 cadaver studies and 3 clinical studies. A total of 1626 perforators from 392 dissected calves, 608 septocutaneous from 345 dissected calves, and 831 musculocutaneous from 292 dissected calves were analyzed [19]. In 2010, Ribuffo et al. conducted an imaging study in which they identified 171 perforators in 82 calves analyzed [20].

The emphasis on preoperative imaging, especially angio-CT, for vascular mapping aligns with the recommendations by Rozen et al. [21]. The study's findings on the average emergence of the peroneal artery at 6.45 cm from the fibular head provide crucial data for surgical planning.

The recent advancements in preoperative planning, including the use of three-dimensional imaging and computer-aided design, have significantly enhanced the precision of fibula flap reconstruction, enabling customization of the graft to fit the specific anatomical and biomechanical requirements of the recipient site, especially in complex maxilla and mandible reconstruction [22,23].

This personalized approach optimizes the functional outcomes of the reconstruction, improving limb salvage rates and patient quality of life [24].

Despite its benefits, the fibula flap technique is not devoid of challenges. The potential for donor-site morbidity, including gait disturbances and lower limb weakness, necessitates careful candidate selection and meticulous surgical technique [25].

Moreover, the complexity of microvascular anastomosis requires a high level of expertise, limiting the procedure to specialized centers.

Summarizing, the fibula free flap stands as a cornerstone in the reconstruction of long bone defects, associating the integration of surgical innovation with the physiological healing processes. Continued research and technological advancements promise to expand its applicability and efficacy, reinforcing its role in the future of reconstructive surgery.

CONCLUSION

This retrospective study sheds light on the multifaceted aspects of utilizing the free transferred fibula flap for limb extensive bone defect reconstruction. The findings underscore the importance of considering patient demographics, anatomical characteristics of the fibula flap, and the strategic use of perforators in achieving favorable outcomes. These insights contribute to the refinement of preoperative planning and procedural techniques, ultimately enhancing the efficacy of this elective therapeutic approach in the clinical management of patients with extensive bone defects. Further studies with larger sample sizes and long-term follow-ups could provide additional depth to our understanding of the outcomes and potential refinements in this surgical modality.

Conflict of interest: none declared
Financial support: none declared

REFERENCES

1. Taylor GI, Miller GD, Ham FJ. The free vascularized bone graft. A clinical extension of microvascular techniques. *Plast Reconstr Surg.* 1975 May;55(5):533-44. doi: 10.1097/00006534-197505000-00002. PMID: 1096183.
2. Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. *Plast Reconstr Surg.* 1989 Jul;84(1):71-9. PMID: 2734406.
3. Wei FC, Celik N, Chen HC, Cheng MH, Huang WC. Combined anterolateral thigh flap and vascularized fibula osteoseptocutaneous flap in reconstruction of extensive composite mandibular defects. *Plast Reconstr Surg.* 2002 Jan;109(1):45-52. doi: 10.1097/00006534-200201000-00008. PMID: 11786790.
4. Rozen WM, Phillips TJ, Ashton MW, Stella DL, Gibson RN, Taylor GI. Preoperative imaging for DIEA perforator flaps: a comparative study of computed tomographic angiography and Doppler ultrasound. *Plast Reconstr Surg.* 2008 Jan;121(1):9-16. doi: 10.1097/01.prs.0000293874.71269.c9. PMID: 18176200.
5. Glynn N, Martin S, Lewis H. The free vascularized fibula flap for long bone reconstruction in adults — a systematic review and regional centre experience. *Eur J Plast Surg.* 2023;46:1199–1211. doi: 10.1007/s00238-023-02082-0.
6. Zaetski A, Amir A, Meller I, Leshem D, Kollender Y, Barnea Y, et al. Free fibula long bone reconstruction in orthopedic oncology: a surgical algorithm for reconstructive options. *Plast Reconstr Surg.* 2004 Jun;113(7):1989-2000. doi: 10.1097/01.prs.0000122213.82011.c5. PMID: 15253188.
7. Campanacci DA, Puccini S, Caff G, Beltrami G, Piccioli A, Innocenti M, Capanna R. Vascularised fibular grafts as a salvage procedure in failed intercalary reconstructions after bone tumour resection of the femur. *Injury*. 2014 Feb;45(2):399-404. doi: 10.1016/j.injury.2013.10.012. Epub 2013 Oct 18. PMID: 24183391.
8. Gupton M, Munjal A, Kang M. Anatomy, Bony Pelvis and Lower Limb: Fibula. [Updated 2023 May 23]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470591/.
9. Godina M. Early microsurgical reconstruction of complex trauma of the extremities. *Plast Reconstr Surg.* 1986 Sep;78(3):285–92.
10. Zeiderman MR, Pu LLQ. Contemporary approach to soft-tissue reconstruction of the lower extremity after trauma. *Burns Trauma.* 2021 Jul 30;9:tkab024. doi: 10.1093/burnst/tkab024. PMID: 34345630; PMCID: PMC8324213.
11. Levin LS. Vascularized fibula graft for the traumatically induced long-bone defect. *J Am Acad Orthop Surg*. 2006;14(10 Spec No.):S175-6. doi: 10.5435/00124635-200600001-00038. PMID: 17003193.
12. Karami RA, Ghieh FM, Saghieh SS, Ibrahim AE. The use of the fibula flap in post oncologic reconstruction of long bone in pediatric patients: A retrospective cohort study. *J Plast Reconstr Aesthet Surg.* 2021 Oct;74(10):2504-2511. doi: 10.1016/j.bjps.2021.03.017. Epub 2021 Mar 29. PMID: 33931323.
13. Houdek MT, Wagner ER, Bishop AT, Shin AY, Rose PS, Sim FH, Moran SL. Complications and Long-Term Outcomes of Free Fibula Reconstruction following Resection of a Malignant Tumor in the Extremities. *Plast Reconstr Surg.* 2017 Feb;139(2):510e-519e. doi: 10.1097/PRS.0000000000003004. PMID: 28121893.
14. Capanna R, Campanacci DA, Belot N, Beltrami G, Manfrini M, Innocenti M, Ceruso M. A new reconstructive technique for intercalary defects of long bones: the association of massive allograft with vascularized fibular autograft. Long-term results and comparison with alternative techniques. *Orthop Clin North Am.* 2007 Jan;38(1):51-60, vi. doi: 10.1016/j.ocl.2006.10.008. PMID: 17145294.
15. Halim AS, Chai SC, Wan Ismail WF, Wan Azman WS, Mat Saad AZ, Wan Z. Long-term outcome of free fibula osteocutaneous flap and massive allograft in the reconstruction of long bone defect. *J Plast Reconstr Aesthet Surg.* 2015 Dec;68(12):1755-62. doi: 10.1016/j.bjps.2015.08.013. Epub 2015 Aug 19. PMID: 26420474.
16. Ettinger KS, Morris JM, Alexander AE, Nathan JM, Arce K. Accuracy and Precision of the Computed Tomographic Angiography Perforator Localization Technique for Virtual Surgical Planning of Composite Osteocutaneous Fibular Free Flaps in Head and Neck Reconstruction. *J Oral Maxillofac Surg.* 2022 Aug;80(8):1434-1444. doi: 10.1016/j.joms.2022.03.018. Epub 2022 Mar 29. PMID: 35461799.
17. Cho BC, Kim SY, Park JW, Baik BS. Blood supply to osteocutaneous free fibula flap and peroneus longus muscle: prospective anatomic study and clinical applications. *Plast Reconstr Surg.* 2001 Dec;108(7):1963-71. doi: 10.1097/00006534-200112000-00019. PMID: 11743385.
18. Yu P, Chang EI, Hanasono MM. Design of a reliable skin paddle for the fibula osteocutaneous flap: perforator anatomy revisited. *Plast Reconstr Surg.* 2011 Aug;128(2):440-446. doi: 10.1097/PRS.0b013e31821e7058. PMID: 21502907.
19. Iorio ML, Cheerharan M, Olding M. A systematic review and pooled analysis of peroneal artery perforators for fibula osteocutaneous and perforator flaps. *Plast Reconstr Surg.* 2012 Sep;130(3):600-607. doi: 10.1097/PRS.0b013e31825dbff3. PMID: 22575854.
20. Ribuffo D, Atzeni M, Saba L, Guerra M, Mallarini G, Proto EB, et al. Clinical study of peroneal artery perforators with computed tomographic angiography: implications for fibular flap harvest. *Surg Radiol Anat.* 2010 Apr;32(4):329-34. doi: 10.1007/s00276-009-0559-y. Epub 2009 Sep 12. PMID: 19756349.
21. Rozen WM, Ashton MW. Modifying techniques in deep inferior epigastric artery perforator flap harvest with the use of preoperative imaging. *ANZ J Surg.* 2009 Sep;79(9):598-603. doi: 10.1111/j.1445-2197.2009.05013.x. PMID: 19895514.
22. Kääriäinen M, Kuuskeri M, Gremoutis G, Kuokkanen H, Miettinen A, Laranne J. Utilization of Three-Dimensional Computer-Aided Preoperative Virtual Planning and Manufacturing in Maxillary and Mandibular Reconstruction with a Microvascular Fibula Flap. *J Reconstr Microsurg.* 2016 Feb;32(2):137-41. doi: 10.1055/s-0035-1563396. Epub 2015 Sep 18. PMID: 26382874.
23. Lo LJ, Lin HH. Applications of three-dimensional imaging techniques in craniomaxillofacial surgery: A literature review. *Biomed J.* 2023 Aug;46(4):100615.
24. Chow LC, Napoli A, Klein MB, Chang J, Rubin GD. Vascular mapping of the leg with multi-detector row CT angiography prior to free-flap transplantation. *Radiology*. 2005 Oct;237(1):353-60. doi: 10.1148/radiol.2371040675. Epub 2005 Aug 11. PMID: 16100083.
25. Momoh AO, Yu P, Skoracki RJ, Liu S, Feng L, Hanasono MM. A prospective cohort study of fibula free flap donor-site morbidity in 157 consecutive patients. *Plast Reconstr Surg.* 2011 Sep;128(3):714-720. doi: 10.1097/PRS.0b013e318221dc2a. PMID: 21572380.