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EVALUATION OF CONFOUNDING FACTORS IN THE FUNCTIONAL AND DENTAL REHABILITATION OF RECONSTRUCTED BALLISTIC DEFECTS USING COMPOSITE ORAL AND MAXILLOFACIAL MICROVASCULAR FIBULAR FLAPS

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Abstract

Background: Reconstruction of the oral and maxillofacial region using a microvascular free fibula flap is practical because of functional rehabilitation and mandibular and maxillary aesthetics using implant-based prostheses following trauma- or malignancy-induced resections. The present research evaluated the role of confounding factors in functional and dental rehabilitation of patients treated with microvascular composition fibula flap or fibula free flap following oral and maxillofacial defects.

Materials and methods: The present research was done as a prospective cohort on 12 eligible patients treated with composite microvascular fibula or fibula free flap following traumatic/ballistic defects of the oral and maxillofacial region. Demographic information, trauma and surgery characteristics, and characteristics associated with patient outcomes, including dysphagia, impaired respiration, mastication, speech, and diet, as well as facial symmetry aesthetic criteria, were recorded. Comparison of the quantitative variables was done using an independent t-test plus analysis of variance, along with their nonparametric equivalents (Mann-Whitney U and Kruskal Wallis test). The results of qualitative variables were evaluated using the Fisher`s exact test.

Results: Dysphagia was observed in four patients (33.33%), impaired respiration in one patient (8.33%), speech impairment in four patients (33.33%), dissatisfaction with facial symmetry in three patients (33.33%), recipient area infection in two patients (16.67%), hematoma in one patient (8.33%), and thrombosis in two patients (16.67%). Further, 10 patients (83.33%) had used implant-based prostheses with 100% success during follow-up period. The frequency of dysphagia

(p=0.007), impaired respiration plus speech, and soft and mixed diet (p=0.007) was higher in the defects of mandibular lateral and anterior region. In other cases, no significant differences were found regarding the outcomes and complications of reconstruction treatments based on gender, site of defects, tobacco smoking, flap components, or lingual resection. These complications were recorded only among active smokers concerning infection, hematoma, and thrombosis in the transplant recipient area. The therapeutic success of the fibula flaps was reported to be 100%.
Conclusion: Therefore, the implantation of composite microvascular flaps or fibular-free flap grafts is associated with high success rates in the reconstruction of traumatic defects in the oral and maxillofacial regions. Nevertheless, in this context there are some considerations about the role of some variables such as smoking and failure site. Patients with lateral and anterior mandibular defects may experience swallowing and feeding problems more frequently, as well as aesthetic concerns.

Keywords: Ballistic defects, Microvascular fibula flap, Traumatic defects, Reconstruction.

1. Introduction

The defects in the maxilla and mandible regions cause problems such as facial deformity, oronasal fistulas, and defective oral function[1, 2]. Today, reconstruction of bony and soft tissue defects in the oral and maxillofacial region has become an important challenge regarding rehabilitating these patients[1, 2]. Considering the nature of this damage and the degree of degeneration that occurs in traumatic and ballistic defects of the oral, maxillofacial and facial areas, the following can be considered[3, 4]. Deterioration of vascular and tissue structures in the transplant recipient area, damage to vital structures and direct damage to functional abilities of certain parts of the face (chewing, breathing, swallowing, speech and aesthetics) are necessary for the reconstruction of these defects. Further studies are needed to address these limitations to be overcome[3, 4]. Microvascular grafting performed in these reconstructions (the gold standard for this treatment) is technically very sensitive, but at the same time causes significant morbidity and financial and infrastructure costs for both patients and hospitals[5, 6]. At the same time, there is increasing interest in using microvascular-free fibular flaps in various fields of reconstructive surgery in the oral, maxillofacial, and facial regions[5, 6].

The Iliac crest, fibula, rib, and radius bones are common donor sites for harvesting vascularized free flaps[1, 7]. Fibula transplantation is superior to other types because of its advantages, such as the large length, which allows for performing numerous osteotomies, sufficient height and width of the bone for implantation, low morbidity of the transplant donor, and the possibility of achieving bony and muscular paddles as well as better angiogenesis[8, 9]. Concurrently, using osseo-cutaneous flaps is associated with successful outcomes in 90% of patients[10, 11].

Advances in microvascular surgery and the use of various microvascular surgical techniques, free fibular skin flaps have become the standard of care in the surgical treatment of mandibular and maxillary defects[12, 13]. The reasons for the superiority of microvascular surgeries include greater blood flow, higher length, remote distance (allowing for surgical operation by two teams), as well as the possibility of applying skin paddle[14, 15]. It has been reported that free osseo-cutaneous fibula flaps are a reliable method for the reconstruction of mandible segmental defects[10, 16]. Also, some researchers have investigated the postsurgical outcomes such as swallowing and returning to oral feeding[10, 16].

Composite free flaps are used to reconstruct the facial structures and associated with acceptable functional improvements, such as of airway function, speech, and mastication, and also provide a basis for dental rehabilitations with implants[17, 18]. In addition, osteointegration of dental implants is successful in fibula-free flaps, and the success rate of implants implanted in fibula without radiotherapy ranges from 69% to 100%[19, 20].. Despite the acceptability of this success rate, these outcomes are seldom significant in case the implants are not loaded functionally. Accordingly, some

studies have examined the survival rate of dental implants following implantation in fibula-free flaps[20].
The present research investigated confounding factors in functional and dental rehabilitation of patients treated with composite microvascular fibula flap or fibula free flap following traumatic defects to the oral and maxillofacial region.

2. Materials and Methods

This study was conducted using a prospective cohort method. To this end, all patients who underwent microvascular composite fibular or fibular-free flap surgery after traumatic/ballistic defects in the oral and maxillofacial region at Taleghani Hospital, Tehran, based on inclusion and exclusion criteria, was recruited.
- Inclusion criteria are: traumatic/ballistic trauma to the face
- use of fibula free flap in the patient
- complete patient file information
- consent to participation in the study

The exclusion criteria included:
- nontraumatic/ballistic trauma to the face
- usage of flaps other than fibula for the patient reconstruction
- no need to bony a free flap
- impossibility of using a fibula flap in the patient
- history of oral and dental malignancies
- history of extensive facial and mandibular trauma
- history of extensive oral and maxillofacial surgery requirement
- history of systemic diseases such as diabetes, and conditions affecting bone metabolism
- Osseous diseases or any drug consumption contributed to osseous metabolism
- death

The patients were followed up for at least six months up to 18 months. The required information of patients which was collected and recorded included demographics (age, gender, place of residence, marital status, smoking, alcohol consumption, and drug abuse), vital signs of the patient (blood pressure, pulse rate, respiration rate). Additionally, trauma-associated features (trauma site, extent of trauma based on involvement of the skin, bone, and mucus), surgery-associated characteristics (length of used fibula, interval between trauma and surgery) were collected. In this work, patient outcome-related features (impairments in swallowing, respiration, mastication, speech, need for nasogastric intubation, and type of diet), along with aesthetic criteria were considered. Aesthetic factors investigated in this study included facial symmetry, and ratings of each aesthetic factor were categorized as satisfactory, acceptable, or unsatisfactory. Patients were divided into three groups: regular diet, soft or mixed diet, and nasogastric intubation diet. Patients' speech was also grouped in three categories: intelligible, fairly intelligible, and unintelligible. Swallowing of patients was explored based on GAG reflections. The defect site was classified into four regions of the anterior maxilla, anterior mandible, lateral mandible without crossing the midline, lateral and anterior mandible. Regarding dental rehabilitation, patients who had implants placed and reconstructed with usable dentures were recorded. The Medical Ethics Committee of Baqiyatallah University of Medical Sciences approved the research (IR.BMSU.BLC.1401.097). Additionally, the study design adhered to the principles of the World Medical Association's Helsinki Declaration on Human Experimentation, as revised in 2000.

2.1. Statistical analysis

Quantitative data were reported by mean and standard deviation, while qualitative data were recorded by number and percentage. Independent t-test and one-way analysis of variance (ANOVA)

were used to statistically compare quantitative variables. The results of qualitative variables were also evaluated per different variables via the Fisher`s exact test.

3. Results

Totally, 12 patients were investigated in this research, nine being male (75.0%) and 3 being female (25.0%). One patient (8.3%) was a non-smoker, 3 (25.0%) were passive smokers, five (41.7%) were previous smokers, and 3 (25.0%) were active smokers. Furthermore, one patient (8.3%) had a drug addiction, while 11 (91.7%) did not have such an addiction. The mean age of the patients was 32.75 years with a standard deviation of 4.09 (age range: 27-40 years). No cases of alcoholism were observed among the patients. Seven patients (58.3%) had no tongue injury. However, tongue rejection occurred in 5 patients (41.7%) with a rate of 1–25%. Maximum mouth opening was average in one patient (8.3%) and normal in the other patients. Ten patients received dental implants and prostheses with 100% success during 6 follow-up periods. Table 1 shows the damaged areas.

Flap components included bone in 8 cases (66.7%) and osteocutaneous components in 4 cases (33.3%). Flap success was reported in all cases (100%). Table 2 shows the means, standard deviations, and central distribution index of quantitative variables such as age, length of bone preserved, and length of fibula used. According to the results of Student's t-test, no significant differences were observed between patients with and without dysphagia regarding age (p=0.07), surgical time (p=0.18), and fibular length used (p=0.33). (Table 3). Based on the results of Student's t-test, no significant differences were observed in age (p = 0.07) and fibula length used (p = 0.33) between patient diet types (Table 4). There were also no significant differences in age per graft recipient site infection (p=0.07), fibular length (p=0.7), or timing of surgery (p=0.41) (Table 5).No significant differences were observed either regarding age (p=0.07), used fibula length (p=0.7), and length of surgery (p=0.41) in samples with and without recipient site thrombosis (Table 6).

The mean fibular length for patients with satisfactory facial symmetry results was 10.80 cm, whereas it was 13.0 cm and 10.33 cm for acceptable and unacceptable facial symmetry results. According to the ANOVA results, no significant difference was found in the fibular length of patients with different facial symmetry scores (p = 0.211).

Based on the Fisher`s exact test results, no significant difference was seen in terms of dysphagia (p=0.1), respiratory dysfunction (p=0.07), speech impairment (p=0.1), diet (p=0.1), facial symmetry (p=0.92), infection (p=0.37), hematoma (p=0.55), and thrombosis (p=0.37) of the transplant recipient site in terms of gender (Table 7). No significant differences were observed either in infection (p=0.07), hematoma (p=0.35), and thrombosis (p=0.07) of the transplant recipient site in terms of tobacco smoking (Table 8). However, there were significant differences in the frequency of dysphagia (p=0.007) and diet (p=0.007) depending on the defect site. Lateral and anterior mandibular defects were more likely to be associated with soft-eating dysphagia. No significant difference was seen regarding the frequency of respiratory dysfunction (p=0.54), speech impairment (p=0.06), facial symmetry (p=0.06), infection (p=0.84), hematoma (p=0.54), and thrombosis (p=0.84) of the transplant recipient site per location of defects (Table 9).

If the face is asymmetrical, defects in the anterior and lateral regions of the mandible will reduce the symmetry of the result. However, it was not statistically significant (p=0.06). On the other hand, there were significant differences in transplant recipient diet type (p=0.39), facial symmetry (p=0.17), infection (p=0.58), hematoma (p=0.14), and thrombosis (p=0.58). No differences were found. Valve components are listed on the site (Table 10).

4. Discussion

Fibula-free transplantation is a reliable and effective method for reconstructing maxillary and mandibular defects. Fibula can resist mastication forces because of its excellent biomechanical features[21, 22]. The morbidity associated with the fibula transplant donor site is also limited, and its associated pains are also minor. In this regard, the present research was done to evaluate the confounding factors in dental and functional rehabilitation of patients treated with composite

microvascular fibula flap or fibula-free flap following traumatic defects of the oral and maxillofacial region in Taleghani Hospital in Tehran in 2022 and 2023.

The results of reconstructions of the oral and maxillofacial region following tumor and trauma surgeries differ from one patient to another because of the disease's different biology and the patient's general health[23, 24]. Concurrently, rehabilitation of oral functions necessitates reconstruction of the defect and oral and dental rehabilitation of patients through implant and prosthesis[24].

In this study, 10 of 12 patients were recommended to receive an implant-based prosthesis and underwent treatment with good results. For most patients treated for traumatic/ballistic defects, the use of implants is considered a routine treatment to restore oral function. Success is limited because the bone into which the implant is placed is grafted and most often undergoes radiation therapy. If the valve is successful, all patients will be able to use an implant-based prosthesis. In this research, the therapeutic success of fibula flaps was 100%, which is considered a complete success for this type of treatment. Lodders et al. (2021) reported a 96% success rate of reconstruction treatments with vascularized free fibula flaps in areas without radiotherapy[25].. Meanwhile, in a retrospective research protocol, Goker et al. (2020) reported an 85.7% success rate for reconstruction of the maxillofacial region with fibula-free flaps[26].. Goker et al. (2020) reported this value as 97.7%[27], while Attia et al. (2018) reported the survival rate of 34 fibula flaps implanted following surgical reconstructions as 97%[28].. Furthermore, Ariga et al. (2017) investigated the clinical and functional outcomes of dental implants placed together with fibula-free flaps following tumor resection. They reported a 100% survival rate for fibula-free flap These findings concur with the present study results. [29].. The survival rate of fibula transplant in the investigation by Parbo et al. (2013) was also reported at 97%, close to the range of previous studies[30].. Some problems, such as loosening the osteosynthesis material, gingival hyperplasia, gingival fistula, and exposure, can lead to flap failure[31]. In one case, the survival rate of the fibula flap in 60 patients with 39-month follow-up was reported to be 98% (9); in research on 42 patients with five-year follow-up, it was 93% (10); and in a study on 18 patients with 10-year follow-up, it was 94% [32].. The high success rate of fibular bone grafting in this study may be due to the limited patient follow-up period of 18 months. The fibular graft material can degrade due to infection, vascular pressure, vascular thrombosis, visibility, and osteosynthesis[33]. [9]. Despite some reports about fibula transplant-associated complications, this transplantation is considered a reliable and safe method[34]. Other factors also affect the survival rate of the fibula graft and the implants inserted into it. These include surgeon skill, bone quality, technical aspects such as implant length, diameter, and initial stability, bone geometry and radiation therapy dose, general health, oral and dental health, and smoking[35]. [34]. Fibular bone grafting allows to modify the osteotomy and reshape the mandible. Due to the large amount of bone available, this flap is also suitable for supporting dental implants. In the present study, the effect of smoking on graft recipient site infection, hematoma, thrombosis, or implant-based prosthesis use/nonuse was not significant. However, these problems, such as infection, hematoma, and thrombosis at the transplant recipient site, were only observed in active smokers. In contrast, non-smokers, former smokers, and passive smokers showed no signs of these problems. Therefore, these small differences may be due to the small number of patients studied. These results suggest a possible influence of smoking on the incidence of complications in fibular flap reconstruction, and patients should receive the necessary warnings in this regard. Considering the influence of smoking on problems such as infections, hematomas, and thrombosis, we can see that smoking can thus influence the outcome of reconstruction. Nevertheless, we note that due to the small number of patients tested in this study, a standard protocol cannot be designed based on the findings or used to treat eligible patients is needed.

In other words, it is impossible to say what the treatment outcome will be if the patient has a particular problem. The effects of tobacco smoking on the success of fibula transplantation and the implanted implants have also been important in previous studies. Burgress et al. (2017) showed that

active smokers (72%) and previous smokers (78%) had a lower success rate of fibula compared to non-smokers (94%)[30]..

This suggests that former smokers are at greater risk of implant failure than non-smokers. Therefore, it is important to investigate smoking history before transplantation preparation and rehabilitation with implants, thereby allowing further interventions to increase the success rate of implant treatment in high-risk individuals. Considering the 100% success rate of fibular bone grafting in the present study, it was not possible to compare success rates when classifying smoking subjects.

Lodders et al. (2021) investigated the long-term outcomes of dental rehabilitation with implants in patients suffering from head and neck cancers following reconstruction with vascularized free fibula flaps. They stated tobacco smoking and radiotherapy in the fibula-free flap area as the predictor variables for the failure of implants[25].

According to the results of this study, 33.33% of patients had dysphagia, 8.33% had breathing problems, 33.33% had speech problems, and 33.33% were dissatisfied with facial symmetry. Meanwhile, graft recipient site infection, hematoma, and thrombosis were observed in 16.67%, 8.33%, and 16.67% of patients, respectively. In the investigation by Gonzalez et al. (2019) regarding swallowing function, penetration was seen in 36% and aspiration in 19% of patients[36]. In the present research, no damage was incurred to the tongue in 16.7% of cases; however, in 52.8% of cases, the tongue had been rejected by 1-25%, which is within the range reported in the present research. In the present research, lingual resection had been done by 1-25% in 41.67% of cases, and there were no significant differences regarding dysphagia, speech impairment, and type of diet in this regard.

In this research, facial symmetry was satisfactory and acceptable in 41.67%, 33.33%, Additionally, the results were unacceptable 25.0% of cases. In the investigation by Bodard et al. (2015), satisfaction was seen in 83.33% of patients due to dental rehabilitation[37]. Aesthetic improvement in most studies on fibula-free flap transplantation is because of the transplant effects on dental rehabilitation[38].

At the same time, in a study by Chiapasco et al., (2011), patients' functional satisfaction was 75.0%, facial contour satisfaction was 100%, and prosthesis aesthetic satisfaction was 83.33%. [39]. Additionally, in another study, 71.6% of patients had adequate aesthetic results, 78.7% had clear speech, and 85.8% had normophagia. [40]. Oral and dental rehabilitation following tumor resection and surgical reconstructions is important for patients because of functional and aesthetic problems[40]. In this regard, using dental implant-based prostheses is one of the suitable options emphasized in the research literature[28, 31]. In this respect, in the present research, 10 patients (83.33%) had also used such prostheses.

In this research, the patients were followed up for 18 months' post-surgery. Studies about this subject have evaluated various time intervals post-surgery, and thus the success rate of implants and free fibula surgeries has diminished over time. Accordingly, Pellegrino et al. (2018) reported 97.2%, 86.5%, and 79.3% success rates for fibula-free transplant implants at 12, 60, and 120 months' post-surgery, respectively[41]. This reduction of success over time indicates the importance of evaluating the efficiency of implant treatment processes in patients who receive fibula-free transplants over time. The decline in the therapeutic success rates over time can be associated with factors such as age, changes in health status, or long-term effects of radiotherapy, causing adverse effects on osteointegration or stability of implants. Subsequent studies should also emphasize the importance of a long-term follow-up period to study the success rate of implant treatment and vascularized free fibula grafting. By screening and reporting treatment success rates at different stages of the follow-up period, potential challenges can be identified and appropriate interventions can be suggested to address them [42-54].

5. Conclusion

Overall, the implantation of microvascular composite flaps or fibula free flap may have a high success rate in the reconstruction of traumatic defects in the oral and maxillofacial regions.

Nevertheless, in this context there are some considerations about the role of some variables such as smoking and failure site. Patients with lateral and anterior mandibular defects may experience swallowing and feeding problems more frequently, as well as aesthetic concerns.

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Table 1. Site of traumatic/ballistic defects of the oral and maxillofacial region in patients undergoing composite microvascular fibula flap or fibula-free flap surgery

Percentage	No.	Site
16.7%	2	Anterior maxilla
41.7%	5	Anterior mandible
8.3%	1	Lateral mandible without crossing the midline
33.33%	4	Lateral and anterior mandible
100%	12	Total

Table 2. Central distribution indices of some quantitative variables in patients undergoing composite microvascular fibula flap or fibula free flap surgery

Variable	Mean	SD	Min.	Max.
Age	32.75	4.09	27	40
Obtained bone length	17.83	2.41	15	20
Used fibula length	11.58	2.58	8	16
The delay between trauma and surgery	103.33	29.22	90	150
Length of surgery	5.96	0.96	5	8

Table 3. Mean and standard deviation of the age, surgery length, and length of fibula used in patients undergoing composite microvascular fibula flap or fibula free flap surgery per dysphagia

Variable	Dysphagia	Mean ± SD	P value
Age	No Yes	31.25±3.24 35.75±4.35	0.07
Length of surgery	No Yes	5.96±1.03 6.05±0.58	0.18
Used fibula length	No Yes	11.88±2.32 10.50±2.08	0.33

Table 4. Mean and standard deviation of the age and length of fibula used in patients undergoing composite microvascular fibula flap or fibula free flap surgery in terms of diet

Variable	Diet	Mean ± SD	P value
Age	Normal Soft and mixed	31.25±3.24 35.75±4.35	0.07
Used fibula length	Normal Soft and mixed	11.88±2.32 10.50±2.08	0.33

Table 5. Mean and standard deviation of the age, length of the used fibula, and length of surgery in patients undergoing composite microvascular fibula flap or fibula free flap surgery per transplant recipient site infection

Variable	Recipient site infection	Mean ± SD	P value
Age	No Yes	31.80±3.62 37.50±3.54	0.07
Used fibula length	No Yes	11.30±1.49 12.00±5.66	0.7
Length of surgery	No Yes	5.85±0.10 6.50±0.71	0.41

Table 6. Mean and standard deviation of the age, length of the used fibula, and length of surgery in patients undergoing composite microvascular fibula flap or fibula free flap surgery per transplant recipient site thrombosis

Variable	Recipient site thrombosis	Mean ± SD	P value
Age	No Yes	31.80±3.62 37.50±3.54	07.0
Used fibula length	No Yes	11.30±1.49 12.00±5.66	7.0
Length of surgery	No Yes	5.85±0.10 6.50±0.71	41.0

Table 7. Results of comparison of different variables in patients undergoing composite microvascular fibula flap or fibula free flap surgery per gender

Variables	Gender Categories	Male	Female	P value
Dysphagia	No Yes	6 3	2 1	1.0
Respiratory disorders	No Yes	9 0	2 1	0.07
Speech disorders	Intelligible Intelligible or unintelligible	6 3	2 1	1.0
Diet	Normal Soft and mixed	6 3	2 1	1.0
Facial symmetry	Satisfactory Acceptable Dissatisfactory	4 3 2	1 1 1	0.92
Recipient site infection	No Yes	7 2	3 0	0.37
Recipient site hematoma	No Yes	8 1	3 0	0.55
Recipient site thrombosis	No Yes	7 2	3 0	0.37

Table 8. Results of comparison of different variables in patients undergoing composite microvascular fibula flap or fibula free flap surgery regarding tobacco smoking

Variables	Cigarette smoking Categories	No	Passive smoker	Previous smoker	Current smoker	P value
Recipient	No	1	3	5	1	0.07

site infection	Yes	0	0	0	2	
Recipient site hematoma	No Yes	1 0	3 0	5 0	2 1	0.35
Recipient site thrombosis	No Yes	1 0	3 0	5 0	1 2	0.07

Table 9. Results of comparison of different variables in patients undergoing composite microvascular fibula flap or fibula free flap surgery per site of defects

Variables	Site of defect Categories	Anterior maxilla	Anterior mandible	Lateral mandible without crossing the midline	Lateral and anterior mandible	P value
Dysphagia	No Yes	2 0	5 0	1 0	0 4	0.007
Respiratory disorders	No Yes	2 0	5 0	1 0	3 1	0.54
Speech disorders	No Yes	0 2	5 0	1 0	2 2	0.06
Diet	Normal Soft and mixed	2 0	5 0	1 0	0 4	0.007
Facial symmetry	Satisfactory Acceptable Dissatisfactory	2 0 0	3 2 0	0 1 0	0 1 3	0.06
Recipient site infection	No Yes	2 0	4 1	1 0	3 1	0.84
Recipient site hematoma	No Yes	2 0	5 0	1 0	3 1	0.54
Recipient site thrombosis	No Yes	2 0	4 1	1 0	3 1	0.84

Table 10. Results of comparison of different variables in patients undergoing composite microvascular fibula flap or fibula free flap surgery per flap components

Variables	Flap components Categories	Bone	Osseo-cutaneous	P value
Diet	Normal	6	2	0.39

	Soft and mixed	2	2	
Facial symmetry	Satisfactory Acceptable Dissatisfactory	3 4 1	2 0 2	0.17
Recipient site infection	No Yes	7 1	3 1	0.58
Recipient site hematoma	No Yes	8 0	3 1	0.14
Recipient site thrombosis	No Yes	7 1	3 1	0.58

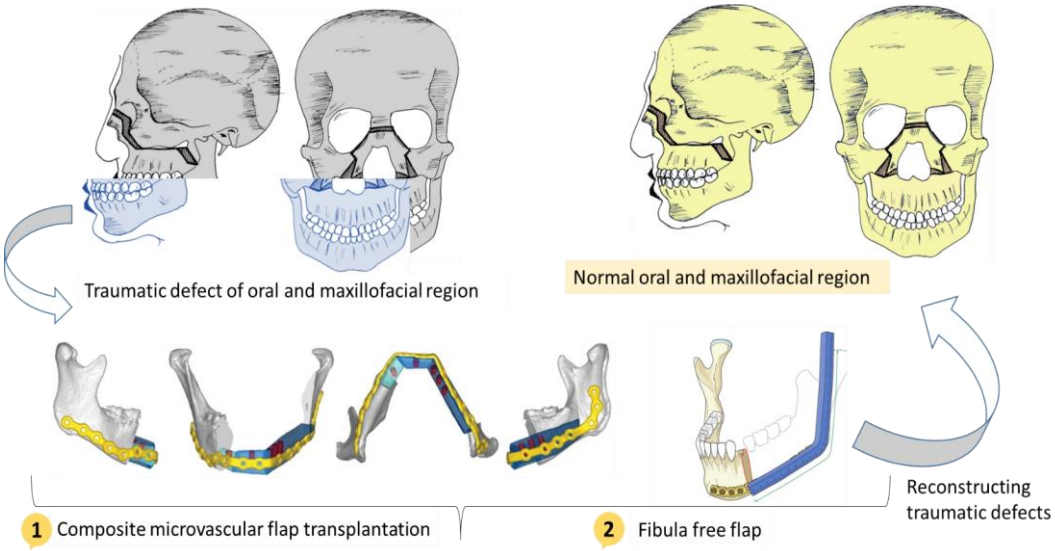

Figure 1: Graphical abstract