Microsurgical Reconstruction of the Jaw With Fibular Grafts and Implants

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Abstract: Reconstructive treatments for jaw defects are complex procedures that can combine multiple techniques including fibula free flap (FFF) grafting. The purpose of this retrospective study was to document and share our experience on mandibular and maxillary reconstruction with FFF followed by secondary dental rehabilitation using implant insertion.

We reviewed 198 patients treated by FFF grafting for mandibular and/or maxillary defects in our department during the past 11 years (1996–2007). A selection of 30 patients (18 males and 12 females, mean age of 46 y) with adequate criteria (hygiene, motivation, and prognosis) received secondary placement of osseointegrated implants. The implant success was clinically and radiographically evaluated.

A total of 105 osseointegrated implants were placed in the grafted fibulas 5 months to 3 years after the reconstruction surgery. Only 4 implants were lost because of peri-implantitis (3 patients) and fibular fracture (1 patient); this corresponds to a 96.2% implant success rate.

During the mean follow-up of 76 months, patient’s satisfaction and functional and aesthetic results were evaluated. Radiologic findings indicated a low crest resorption around the implants despite an unfavorable crown-to-root ratio.

The main difficulties in the reconstructions were lack of FFF height, absence of a vestibular groove, limitation of mouth opening, skin paddle thickness, and the reconstruction of surrounding tissues including the lip. Our management strategy is discussed.

Prosthetic choice is fundamental to achieving patient-specific solutions. The prostheses used included sealed or screwed bridge, resin-bonded bridge, tooled bar, implant-borne denture, or implant-stabilized dentures. Dental implants may be used even in situations involving an unfavorable crown-to-root ratio and implant position by using milled bar and overdenture. The FFF provides a consistent bone graft that allows a reliable and predictable restoration with dental implants, leading to a satisfactory functional and aesthetic restoration.

Key Words: Jaw reconstruction, fibula free flap, dental implants, tooth rehabilitation, radiotherapy, prosthesis

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Large jaws and adjacent tissues defects are a challenge for reconstructive surgeons and prosthetic dentists. The levels of difficulty in reconstruction procedures after jaws resection are as follows (in order of importance): first, the soft tissues for closing the mouth; second, the hard tissue for jaw support and facial contours; and third, the dental restoration for function and aesthetics.

Despite some controversies, during the past decade, the vascularized fibula free flap (FFF) has become the most popular choice for reconstruction of large jaw defects.1 For mandibular reconstruction, FFF seems to be the best choice owing to its length, its height, and the possibility to reshape and restore the mandibular arch.2 For maxillary reconstruction, several choices are available: parascapular flap, iliac crest,3,4 or FFF.5 We prefer the FFF especially for its reliability, its pedicle length, and the possibility to obtain suitable shape. Furthermore, this type of bone reconstruction should widely allow an implant-retained prosthesis.6

The aim of this review was to evaluate the rehabilitation of 30 patients treated by 31 FFF graft in combination with delayed dental implant restorations. The advantages and difficulties of oral rehabilitation with dental implant in FF for mandibular and/or maxilla reconstruction were analyzed.

This retrospective study was aimed at documenting and sharing our experience on reconstructing the maxilla and the mandible with FFF followed by secondary dental implantation, prosthetic choice, and preprosthetic procedures.

PATIENTS AND METHODS

Patients who underwent reconstruction of mandibular and/or maxillary defects with FFF from 1996 to 2007 in the Department of Oral and Maxillofacial Surgery of Lille were analyzed.

Some of these patients were considered candidate for implant rehabilitation based on the following 3 criteria:

Initial status
• Existing denture or prosthesis before jaw resection and/or reconstruction
• Good dental and oral hygiene and cessation of both alcohol and tobacco use
• Patient’s motivation for oral rehabilitation involving additional surgical procedures
Residual function
- Mouth opening adequate for prosthetic height and implant placement
- Sufficient residual or sequelae tongue function for swallowing

Preprosthetic procedures
- Adequate maxillomandibular relationship (preprosthetic surgery may be necessary)
- Lips’ competence with prosthesis (surgical reconstruction or management of the lips may be needed).

To identify optimal conditions for prosthetic results, all these criteria were studied. If one of the criteria was absent, we did not suggest implant placement except after an improvement of the situation.

Of the patients in this retrospective study, only those who were reconstructed by FFF and had secondary implant insertion were considered for further analysis.

The data for this selected group of patients were analyzed for age, sex, initial lesion, location of jaw resection, radiotherapy before or after implant placement, dimension of the reconstruction, use of...
skin paddle, delay before implant placement, number and position of the implants, use of preprosthetic and postprosthetic procedures, and prosthesis type.

Functional evaluation of the results after prosthesis rehabilitation was performed on the basis of masticatory performance, speech, and saliva control. Lip and cheek support (aesthetic and functional result) were evaluated by clinical examination and subjectively by the patients at interview. Evaluation of peri-implant marginal bone loss was done with periodic panoramic radiograph during the follow-up period.

RESULTS

Patients

In the 11-year period from 1996 to 2007, 198 patients had jaw reconstruction by FFF. Thirty of these patients subsequently benefited from placement of osseointegrated implants in 31 FFF. At implant insertion, patients’ age ranged from 19 to 72 years (mean, 46 y). There were 18 men and 12 women.

Initial Pathologic Findings

The etiology of the defects is listed in Table 1. Resection for malignant tumor or osteoradionecrosis occurred in 20 patients and for a benign tumor in 4 patients. Although 14 patients received radiotherapy, 8 had secondary jaw reconstructions so only in the 6 other patients was the FFF itself irradiated. Gun blast injury was the cause in 4 patients (1 patient with bimaxillary reconstruction: patient 20/20). Finally, in 1 patient, the cause was a mandibular fracture on an edentulous mandible, and in the other, the cause was after a major cleft lip and palate.

Defect and Reconstruction Location

Graft sites were the mandible in 25 patients and the maxilla in 6 patients. Jaw defect classification was described according to Brown et al7 for the maxilla and Jewer et al8 for the mandible (Fig. 1).

Dental Status

Before surgery, 2 patients were completely edentulous but wore prosthesis; the dentition of the others was partially removed during resection. This situation led to our inclusion criteria for dental restoration.

Free Flap and Skin Paddle

The FFF were used after “bloc” resection in all patients. A skin paddle was used in 25 patients (81%). In 24 patients, skin paddle was inserted intraorally to close the mucosal defect and was used for clinical evaluation of the flap vitality (1 patient had skin paddle placed in the neck).

Preprosthetic Procedures

In 1 patient, mandibular osteotomy was required before implant rehabilitation.

![Figure 1](https://example.com/figure1.png)

**FIGURE 1.** Bone defect localization and patient numbers. A, Situation of the mandibulectomy defect using LCL classification from Jewer et al. B, Maxillary defect localization as described by Brown et al. For mandibular defect: L = 15, H = 2, C = 1, LC = 4, and LCL = 3. For maxillary defect: class 2a = 2, class 2b = 2, class 2c = 2.
During implant insertion, we removed the titanium mini-plates and reconstruction blades if they were a source of pain or infection or if they blocked implant placement.

**Implant Placement**

Before inserting the dental implants, radiologic examinations were performed to exclude any pathologic bone alteration. Primary implant stability was always very high owing to the fibula bicortical structure. One hundred five endosseous dental implants were inserted (varied from 2 to 6 implants per fibula). This involved the anterior dental sector in 10 patients, lateral sector in 12 patients, and posterior portion in 9 patients.

Implant placement was delayed from 5 to 51 months after the reconstruction (mean, 16 mo) to allow bone healing, to allow resolution of radiation therapy effects, and to organize preprosthetic surgical steps. In all patients, a minimum of 5 months’ (range, 5–18 mo; mean, 8 mo) latency period was allowed for osseointegration before implant loading.

Implants were placed bicortically into the grafted fibular except in 5 patients with monocortical insertion.

**Preprosthetics Procedures**

Final thinning down of the overlying soft tissues was necessary and was performed at the time when the healing abutments were inserted in 23 patients (74%). A mucosal or skin graft was then necessary in 6 patients (19%) to manage soft tissue around abutments (Table 1).

Lip surgery was necessary for 8 patients (26%) involving surgical lip repositioning in 4 patients. Lip reconstruction and lengthening was necessary for 3 patients. A nasolabial flap was used for the patient 20/20° and Dufourmentel flap for patient 28. The third patient had had refinement and repositioning after debridement (patient 27).

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**Table 2. Description and Nature of Prosthetic Rehabilitations, Their Problems, Their Functional, and Aesthetic Results for Each Patient**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Prosthesis Description</th>
<th>Prosthesis Troubles*</th>
<th>Function and Aesthetics†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prosthesis Type</td>
<td>Framework</td>
<td>Implant-Framework Fixation</td>
</tr>
<tr>
<td>1</td>
<td>IBD Bar</td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>IBD Bar</td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Bridge Bridge</td>
<td>S</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Bridge Bridge</td>
<td>S</td>
<td>0</td>
</tr>
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<td>5</td>
<td>IBD Bar</td>
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<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Bridge Bridge</td>
<td>C</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>IBD Bar</td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>IBD Bar</td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>IBD Bar</td>
<td>S</td>
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</tr>
<tr>
<td>11</td>
<td>IBD Bar</td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>IBD Bar</td>
<td>S</td>
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</tr>
<tr>
<td>13</td>
<td>Bridge Bridge</td>
<td>C</td>
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<td>14</td>
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</tr>
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<td>15</td>
<td>IBD Bar</td>
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<tr>
<td>16</td>
<td>IBD Bar</td>
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<td>17</td>
<td>ISD Ball</td>
<td>S</td>
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</tr>
<tr>
<td>18</td>
<td>IBD Bar</td>
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</tr>
<tr>
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<td>IBD Bar</td>
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<td>1</td>
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<td>22</td>
<td>IBD Bar</td>
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<tr>
<td>23</td>
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<td>25</td>
<td>Bridge Bridge</td>
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<td>26</td>
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<td>27</td>
<td>IBD 2 bars</td>
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<td>RBB Bridge</td>
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</tr>
<tr>
<td>31</td>
<td>ISD Bar</td>
<td>S</td>
<td>1</td>
</tr>
</tbody>
</table>

| Total no. | 24 | 17 | 20 | 20 | 27 | 53 | 53 | 56 |
| Percentage| 77%| 55%| 65%| 65%| 87%| 85%| 85%| 90%|

C indicates cemented; IBD, implant-borne denture; ISD, implant-stabilized denture; RBB, resin-bonded bridge; S, screwed.

*Yes = 1, no = 0.
†Excellent = 2, good = 1, bad = 0.
Prosthesis

Dental restoration was undertaken and effective in all patients, despite the reduced bone height and the low position of the graft in addition to the limited mouth opening (17 patients, 55%), which was a problem for posterior sector implant insertion.

Prosthetic rehabilitation used several types of fixations: conventional bridge (5 patients, 16%), resin-bonded bridge (2 patients, 6%), implant-borne denture (19 patients, 62%), and implant-stabilized denture (5 patients, 16%; Table 2).

The main prosthetic difficulties were caused by an abnormal relationship between the upper and the lower dental arches with shifted implant abutments (20 patients, 65%), vertical discrepancies involving an unfavorable crown-to-root ratio (20 patients, 65%), loss of oral vestibular groove, and presence of granulation tissue around the implant because of lack of attached gingival (27 patients, 87%), leading to palatal or skin graft around permanent abutments as described in Table 1.

Functional and Aesthetic Results

After a mean follow-up period of 76 months, functional and aesthetic results were considered good to excellent for all our patients, as shown in Table 2. We evaluated normal eating, improved speech ability, restored labial competence, and facial outline. Concerning patient 23, the aesthetic result and chewing ability was

<table>
<thead>
<tr>
<th>TABLE 3. Implant Timing, Follow-Up, and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implant Results</strong></td>
</tr>
<tr>
<td>Patient No. Onset FFF – Implant Insertion, mo</td>
</tr>
<tr>
<td>1 6 38 6 155 4</td>
</tr>
<tr>
<td>8 9 46 7 111 3</td>
</tr>
<tr>
<td>15 14 19 8 79 2</td>
</tr>
<tr>
<td>21 12 39 7 38 3</td>
</tr>
<tr>
<td>29 12 53 7 15 2</td>
</tr>
<tr>
<td>Median</td>
</tr>
<tr>
<td>Total no.</td>
</tr>
</tbody>
</table>
| 105 | | | | | | Implant success rate = 96.19%.

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considered bad owing to the soft tissues and lip retraction. Unfortunately, the patient died of lung carcinoma before management of postprosthetic procedures could be carried out. Overall percentage score were calculated for chewing ability (85%), speech improvement (85%), and aesthetic result (90%) including lip support, prosthesis integration, and facial outline.

**Implant Success Rate**

As mentioned in Table 3, we observed 4 implants losses because of peri-implantitis in 3 patients and 1 fibular fracture in the fourth (Fig. 4). Our success rate is 96.2% and is similar to reports in the literature (Table 4). 9,10,12 Patient follow-up ranged from 7 to 155 months (mean, 76 mo) after implant placement. To date, no patient has experienced mobility of implants after loading.

**Radiographic Evaluation**

Radiographic evaluation showed that dense cortical bone was present around the necks of all the implants. We observed an average fibular crest resorption of 3 mm in 16 patients; no crest resorption in 14 patients. In 1 patient, we saw an increase of bone after implant loading (Fig. 4).

**DISCUSSION**

**Selection Criteria for Implant Placement**

To get an optimal prosthetic result, restrictive criteria were applied to all patients. If one of the criteria was absent, the patient was informed, and the indication of implant placement was withdrawn. All the criteria were discussed with each patient and could be reconsidered after a while, thereby allowing remotivation, reeducation, or lip surgery if required.

**Initial Dental Status**

**Existing Denture or Prosthesis Before Jaw Resection and/or Reconstruction**

If patients have previous dental restorations or teeth, an offer of dental restoration is always made after the jaw reconstruction surgery. In our opinion, dental restoration must be proposed to patients having previous dental rehabilitation or teeth, before jaw resection. In that situation, dental restoration is a part of the jaw reconstruction. If patients were edentulous before the reconstruction, it is not necessary to do dental restoration. The aim was not to give teeth to someone who did not have them before reconstruction.

**Dental and Oral Hygiene**

Endosseous implants require strict oral hygiene and motivation. Complete cessation of smoking and alcohol consumption is also necessary and may constitute an additional motivation. 13

**Patient Motivation for Oral Rehabilitation Involving Additional Surgical Procedures**

To get optimal placement of implants, additional preprosthetic and postprosthetic procedures are often necessary. This was explained to patients beforehand, and they had to accept those procedures. Some degree of residual function (chewing, swallowing, maintaining lip seal, etc) must be present to improve the situation by dental rehabilitation.

**Residual Function**

**Mouth Opening for Prosthetic Height and Implant Placement**

To permit implant insertion and allow sufficient interocclusal space for chewing and swallowing, we estimate that a minimum space of 15 mm is necessary. Some patients did not meet this condition initially, but after physiotherapy, they managed to gain enough to allow implant placement.

**Sufficient Residual Tongue Function for Swallowing**

Prosthetic rehabilitation improves aesthetics and function, but if the patient does not eat with prosthesis, or cannot eat, prosthetic rehabilitation using implants is not necessary and was not offered. In that situation, depending on the origin of the limitation, reeducation stages may be proposed to permit swallowing and chewing. In conclusion, prosthetics are meant for improving chewing and swallowing.

**Preprosthetic Procedures**

**Sufficient Maxillomandibular Relationship**

To get optimal dental and prosthetic contacts between jaws, alignment must be sufficient between jaws to reduce level arm effect on implants. Orthognatic preprosthetic surgery may be required in some patients to deal with this problem.

**Oral Competence With Prosthesis**

The lip must cover the prosthesis from a functional and aesthetic point of view. Without lip coverage, saliva and food leaking will result in patient dissatisfaction. Surgical reconstruction or management of the lips may be required to achieve this.

By using these criteria, only a minority of patients qualified for implants after FFF (of 198 FFF patients, only 16% benefited from implant-retained prosthesis), but the strict selection led to both a high implant success rate and a high level of satisfaction. Patients are also involved in the decisions regarding physiotherapy, hygiene, cessation of alcohol and tobacco consumption, and additional surgery.

**Choice for Bone Reconstruction**

The anatomic rebuilding of the mandible or the maxilla constitutes itself a difficult task for the surgeon. With the development of reconstructive microchirurgical techniques, large advances occurred in the outcome of jaw reconstructions. 9,10,11 Currently, the combined reconstruction of overlying mucosa, bone, and cutaneous structures offers better results, compared with the former treatments using pedicle flaps. 12 The good functional result were related also to the retention of denture supported by osseointegrated implants. 9,12

The fibula osteocutaneous flap has been used for mandibular reconstruction since 1987. 9,10,11 This flap provides adequate tissue amount to restore various degrees of mandibular or maxillary bone defects: it is also easy to adapt to the mandibular form using one or several osteotomies, 20,21 bispurate, or double-barreled gun FFF. 21

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**Table 4. Osseointegrated Implants Loss and Survival Rates Through Literature**

<table>
<thead>
<tr>
<th>Study</th>
<th>No. Implants</th>
<th>Implant Loss</th>
<th>Survival Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roumanas et al</td>
<td>54</td>
<td>5</td>
<td>90.7</td>
</tr>
<tr>
<td>Garrett et al</td>
<td>58</td>
<td>3</td>
<td>94.8</td>
</tr>
<tr>
<td>Chiapasco et al</td>
<td>60</td>
<td>4</td>
<td>93.3</td>
</tr>
<tr>
<td>Our study</td>
<td>105</td>
<td>4</td>
<td>96.2</td>
</tr>
<tr>
<td>Gbara et al</td>
<td>121</td>
<td>4</td>
<td>96.7</td>
</tr>
</tbody>
</table>

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Implant Insertion in FFF

The introduction of osseointegration concept and its application for dental rehabilitation has greatly improved the rehabilitative potential for patients with large jaw defects. The development of endosseous implants in FFF has eliminated many problems related to the retention and stability of conventional prosthesis and reduced prosthetic rehabilitation problems in irradiated patients (45% of our patients) with reduced salivary flow.

Implantation is possible because the height of the fibula shaft is always at least 10 mm but not always in the ideal axis. This accounts for the unfavorable implant axis and interval between prosthesis and abutments connexions present in 65% of the patients. To avoid this situation, the double-barreled gun fibula is advocated. In nonatrophied dentate mandibles, the application of a double-barreled gun fibular transplant compensates the height of the transplant; similarly, fibular distraction is also suggested to create better prerequisites for prosthetic management. In nonirradiated grafts, it may be possible to use additional nonvascularized graft from the cranial vault or the iliac crest. Those techniques are the same as in a native atrophied jaw. We did not use the double-barreled gun fibular flap for the patients described here, but we were still able to obtain good results. In our study, the double-barreled gun FFF was used in 3 of the 198 patients, but they were not implanted because of locoregional cancer recurrence.

Another prosthetic difficulty was caused by an abnormal intermaxillary relationship, which is usually compensated by adaptation of abutments axes and size; in our study, we have done fibular osteotomy in 1 patient to adapt maxillomandibular relationship.

Numerous studies have documented the advantages of using fibular bone, which is bicortical and thus can provide better fixation for the implants and allow long models (13 mm). A recent experimental study concluded that the implants’ primary mechanical stability placed in the fibula is higher than that placed in the iliac crest and the scapula. In addition, the double-barreled gun fibula provides a wide choice of prosthetic rehabilitation.

In this study, we obtained the same result described in other publications (Table 4), so we conclude that fibular bone height was not restrictive and that prosthetic rehabilitation is also possible without using a double fibular transplant. In our experience, a covered implant technique was used. The first surgical stage was implant insertion and soft tissue management. The second surgical stage was to make transmucosal or transcutaneous (in case of skin paddle) healing abutments and dental impressions. Finally, loading was delayed until for a minimum of 5 months after implant insertion, especially in irradiated bone and according to the radiation dose.

A 1-stage procedure is also a good option if the FFFs are not irradiated and soft tissue management is not required. This approach is now in use for our current patients based on the good result obtained in this study.

Timing for Implant Insertion

Implants may be inserted at the same time as reconstruction procedures. However, Roumanas et al reported that the only implants demonstrating bone loss are those that were placed immediately at the time of the reconstruction and those that were subsequently irradiated. The first disadvantage for implant insertion during the reconstruction stage is the difficulty of placement of a subsequent prosthesis at a later stage. In addition, in case of malignant tumor, resection may be insufficient and involve a part of the reconstructed jaw.

Another level of complication is related to the success of the graft itself. Fibula free flap has a high success rate, but not 100%, so if implants are inserted at the time of the FFF reconstruction, there is a chance of losing them with failure of the FFF graft. Microsurgical reconstructions are time-consuming procedures, and if implant insertion is added at the end of the reconstruction, this can lead to very long surgery times. Delaying implant insertion means shorter reconstruction surgery, hence reduced anesthesia duration and morbidity and, in addition, avoidance of exposing implants to radiotherapy.

As a rule, in Lille, we do implant insertion after bone reconstruction and radiotherapy (if indicated); this procedure provides better matching of implant placement to the choice of prosthesis.

Preprosthetic Procedures

There are some surgical and prosthetic difficulties associated with this combined functional restoration, as shown in Table 1. First, the use of skin paddles in most patients (81%) leads to refinements and thinning (74%), with palatal or skin graft (19%) due to the lack of attached gingiva around abutments. In most of the patients, the skin paddle seems to be a source of peri-implant infection owing to its thickness and the lack of attached tissue. Because it is combined with neck dissection for vessel preparation and sometimes lymph node resection, formation of a sinus may lead to otorrhea. On the other hand, free flap vascularization is really easy to survey by using skin paddle examination, which can be done by anyone on the medical and paramedical team. There is often the opportunity to remove it, at least partially, after FFF healing and sometimes after radiotherapy.

Lip reconstruction is part of the soft tissue management, but this needs additional surgical planning. Lips are the most difficult parts to reconstruct. They need height, thickness, active mobility, passive stability, and possibility to touch each other once the patient wears the prosthesis. Two patients needed lip reconstruction. In addition, lip surgery was necessary in 26% of the patients: lip and chin debridement and repositioning, superior lip lengthening, and inferior lip lengthening.

The first patient lacked half of the upper lip after gun blast injury. At the end of the bony reconstruction, soft tissues have been reshaped. The final intervention was a nasolabial flap was used to gain lip height on the skinned side: the mucosal side was provided by the fibular skin paddle (Fig. 7).

The second patient had total chin and inferior lip resection, except the half lip orbicularis muscle. To gain the mucosal inner side, we performed 2 crossed buccal flaps in 2 different stages because of ligature of both facial pedicles during lymph node dissection and microvascular graft of the fibula. To gain the skinned side of the inferior lip, we use a bipedicled Dufourmentel flap (Fig. 9). After weaning, only the top of the cranial vault needed a further 5 weeks’ healing time. The 2 pedicles were replaced to cover the temporal defect.

Lip reconstruction is absolutely necessary to wear a prosthesis for chewing. If no lip reconstruction is provided, the prosthesis is useless. A prosthesis needs lip coverage for function and for supporting them to improve aesthetics. Without these procedures, lip height was insufficient for prosthetic coverage and lip contact. Those periprosthetic procedures were difficult for the patient but fundamental to meet our selection criteria.
Mouth Opening Limitation
Mouth opening limitation is frequently noticed (55%). If the anterior vertical distance between incisors is less than 15 mm, we did not recommend dental implants: Dental impressions are of poor quality, and implant insertion may be impossible. We consider mouth opening of 30 mm or less as “limited.”

Functional and Aesthetic Results
Chewing quality has been greatly improved (85% score) in all patients except one who died before lip debridement.
Speech improvement was noticed for all patients (85% score) by restoring denture and avoiding air outflow.
Aesthetic result was also considered as very good (90% score) by restoring facial outline and providing dental rehabilitation with steady dental relationship.

Irradiated FFF
In our study, in agreement with Smolka, existence or absence of radiotherapy had no influence either on success of dental rehabilitation in general or on implant survival. In our practice, we always ask for dosimetry curves given by radiotherapist to avoid implant placement in an area that has received more than 50 Gy. There is no real consensus on that level of irradiation, but in our hands, it seems to be a reasonable limit. When radiotherapy exceeds 50 Gy, we estimate that the risk of implantitis and osteoradionecrosis is too great, and then we do not recommend implant insertion. In our study, implant loss was seen only in one irradiated FFF.

Implant Failure
Reasons for implant failure are described as follows:
- Patient 10 had a peri-implantitis and mobility before loading.
- Patient 13 had a peri-implantitis with painful mobility before loading.
- Patient 23 had a spontaneous fibula fracture around the implant. After spontaneous bone healing, implant was outside the bone and was removed during skin paddle thinning and abutments positioning.
- Patient 26 had a lack of primary stability. The implant was inserted in a fibular osteotomy and had to be removed a few days afterward. Concerning osseointegrated implants, the comparison of our results with the literature findings revealed no differences in the complication rate and the implant survival rates (Table 4).

Bone Height Surrounding Implants
Bone resorption was seen in 14 patients, with an average height of 3 mm. In other patients, no bone resorption was seen, and a bone increase was noticed in only 1 patient. The patient had sarcoma with primary chemotherapy, and mandibular resection was reconstructed by FFF and skin paddle. Five weeks after implant placement, the fourth implant was lost owing to pathologic fracture during chewing. No treatment was done, except soft diet. Spontaneous healing was achieved, and a prosthesis was built. One year after loading, we noticed 1-mm osseous gain on both sides of the implants around the implant neck and its basilar area. Biomechanical stimulation by loading is supposed to be responsible for this response (Fig. 4).

Prosthetic Choices
The prosthetic realization is often difficult because of the adverse effects of therapy (surgery or radiotherapy) resulting in limited mouth opening or wrong position of the available bone for implant insertion. Depending on those different limitations and the presence of natural teeth, we may use conventional implant supported bridge, resin-bonded bridge, implant-borne denture, and implant-stabilized denture. Removable dentures (implant-borne denture and implant-stabilized denture) were used 24 times in our study (corresponding to a rate of 77%), and fixed denture (conventional bridge and resin-bonded bridge) was used 7 times in our study (corresponding to a rate of 33%; Table 2). The best option is to provide a fixed denture, but it may not be suitable for every situation depending on the implant axis and crown-to-root ratio and the number of implants (Table 5).

Bridge
The bridge is the criterion standard, screwed or cemented, but needs perfect alignment and favorable crown-to-root ratio. The number of implants is also important for bridge prosthesis. Implant axis inclination can be accommodated, but only small angularizations are compatible with maintaining a biomechanical force transmission in a favorable orientation for implant success. We used it in 5 patients, for maxilla or mandible. That prosthetic rehabilitation was possible because of the favorable position of the fibula (Figs. 2 and 3).

Resin-Bonded Bridge
Conventional FFF mandibular reconstruction is placed in the lower portion of the mandible, resulting in a low position of the grafted

| TABLE 5. Prosthetic Choices Comparison for FFF Rehabilitation |
|---------------------------------|-----------------|-----------------|
|                              | No. Implants    | Implant-Abutment Alignment | Crown-to-Root Ratio | Prosthesis-Implant Neck Emergence Interval |
| Conventional bridge (Figs. 2 and 3) | ++++            | ++++                     | +++              | +++   |
| RBB (Figs. 4 and 5)              | ++++            | ++                      | ++               | ++    |
| IBD (Figs. 6 and 7)             | ++             | +                       | +                | +     |
| ISD with bar-splinted attachment (Fig. 8) | ++             | +                       | +                | +     |
| ISD with free-standing attachment (Fig. 9) | +               | ++                      | +                | +     |

Importance of each criteria by means of relative score: ++++, very high; ++, high; +, fair; +, low.
IBD indicates implant-borne denture; ISD, implant-stabilized denture; RBB, resin-bonded bridge.
bone. In our experience, the limited width of the fibula was a problem in many patients for making dental impressions, implant placement, and prosthesis rehabilitation. Implants are usually placed with an axis given by the maximal height available. We often notice an unfavorable crown-to-root ratio (20 patients, 65%) and a shifted implant axis compared with the ideal prosthesis situation (20 patients, 65%).

In some patients, the difference in height between the fibula and the atrophied mandible or maxilla was slight. The height difference is compensated by the prosthesis. Implant axis tilt may be accommodated, but it is better to build the metal framework without inclined abutments and perform axis correction at the level of the prosthesis. To get suitable force transmission and to protect implants, plastic teeth and gingiva are bonded to the metal framework. This solution provides a fixed denture and acts as a damper protecting the metal framework and implants. A Maryland bridge or resin-bonded bridge seems to be a good choice to solve several problems. The metal framework is either cemented or screwed to the implants abutments, and the resin is bonded to the framework, restoring teeth crown and attached gum. The advantages of resin-bonded bridge are as follows: provide fixed denture with good occlusion and implant axis correction. Aesthetic result is also good in such situations.

The high loading resulting from the high vertical dimension of the prosthesis and unfavorable implant axis could lead to implants overloading and could endanger longevity of prosthetic restoration (lever arm effect). However, up-to-date, no study has proven this theory on fibular flaps. We used Maryland bridge in 2 patients (Figs. 4 and 5), but no overloading problem of this type occurred in our experience.

**Implant-Borne Denture**

The main problem for prosthetic rehabilitation is the shifted position of implants emergence compared with the ideal one. Usually, the implants have a vestibular position that will not allow use of a conventional bridge. Our solution, used for maxilla and mandible, is the realization of a milled bar supporting a removable overdenture. The overdenture will hide and protect the bar and permit perfect occlusion. The bar is usually screwed. For the patient, the main disadvantage is removal of the denture, but it seems to facilitate abutment cleaning and survey disease recurrence. Implant-borne dentures are useful for correcting poor implant alignment because the framework links all the implants and permit biomechanical forces repartition.
Mouth opening limitation will prevent implants insertion in the posterior sectors and will often induce a vestibular axis. This situation limits the possibilities of prosthetic rehabilitation. It may be corrected by using cantilever on the overdenture and extend the prosthesis to the desired area (Figs. 6 and 7).

**Implant-Stabilized Denture**

Implant-stabilized denture is the last choice for prosthetics. The implant-stabilized denture can be stabilized with as few as 2 implants. We only use it for large resection and/or edentulous patients with mouth opening limitation. This choice permits implant insertion in the anterior sector. A bar-plinted or free-standing (o’ring) attachment may be used. The disadvantages are the removable denture and the mucosal support. The advantages are the low forces transmitted to implants, the few implants needed to stabilize the whole denture, the easy abutments cleaning, and mucosal examination especially in cancer follow-up (Figs. 8 and 9).

The main advantages of jaws reconstruction using an FFF have been reviewed in our study; they provide a suitable amount of bone width and height to support osseointegrated implants for

**FIGURE 4.** Patient no. 23: A, Computed tomographic scan showing a limited sarcoma of the left horizontal branch of the mandible. B, After chemotherapy and resection, a reconstruction has been performed by an FFF. C, Four implants were inserted. One was lost because of pathologic fracture before loading. D, Resin-bonded bridge over 3 implants was made. E, Occlusion showing unfavorable implants position and crown-to-root ratio. F, Intraoral view with opened mouth showing skin paddle.

**FIGURE 5.** Patient no. 30: A, Panoramic radiograph showing FFF reconstruction of the left mandible after a sarcoma large resection involving temporomandibular joint. B, Three implants were inserted with resin-bonded bridge. Clinical intraoral view in occlusion (C) and in mouth opened posture (D).
prosthetic rehabilitation, improving speech, swallowing, and aesthetic appearance. The survival rate of dental implants within the fibular graft is excellent, with low crestal bone resorption over the years, even with an unfavorable crown-to-root ratio and wrong alignment with prosthesis. Especially for irradiated patients, endosseous implants will be the best choice to get dental rehabilitation.

**FIGURE 6.** Patient no. 8: A, Panoramic radiograph showing 3 implants placed in an FFF reconstructing a left mandibular sarcoma after chemotherapy and resection. B, Intraoral view of the tooled bar with wrong implant axis alignment. C, Implant-borne denture with anterior, lateral, and posterior cantilever.

**FIGURE 7.** Patient no. 20/20: A, Clinical view of the patient face after a gun blast with large disfiguration involving both mandibular and maxillary defects. B, Panoramic radiograph showing the realized reconstruction: mandibular FFF, pedicled pectoralis major flap, and second FFF for maxilla. C, Clinical aspect after first labial refining. D, Panoramic view after implants insertion. Intraoral upper (E) and lower (F) views with milled bar allowing correction of implant wrong alignment. G, Lip defect and insufficiency in case of closed mouth with prosthesis. H, Benefit of the functional result after nasolabial flap, chin fixation, and cervical lipectomy. I, Final aspect of mouth opening after having worn prosthesis. In this situation, a conventional bridge was not used because an overdenture was needed to provide labial support.
For partial resections with remaining teeth, if bone graft can allow perfect alignment and favorable crown-to-root ratio, conventional bridge is preferred.

A milled bar with overdenture seems to be our best choice, especially when double-barreled gun FFF is not performed, for correcting implant axis and prosthesis height. The solution between the bridge and the implant-borne denture is the resin-bonded bridge.

For total resection and edentulous patients, implant-stabilized prostheses, especially for mandibular, were the best choice. In all those patients, the low bone height achieved in the absence of double-barreled gun reconstruction was not an obstacle to achieve a satisfactory result for the patients (Table 5). An overdenture is one of the best choices to resolve prosthetic difficulties, permitting the hiding of a cantilever and any lateral shift of the implants compared with the natural denture.

Careful consideration must be given to the selection of candidate patients for implant rehabilitation, and functional and cosmetic aspects of reconstruction need to be considered in preoperative planning. The patient is widely involved in the prosthetic choice.

**FIGURE 8.** Patient no. 31: A, Panoramic view of a patient presenting a very large anterior verrucous squamous cell carcinoma of the mandibular. B, It has involved LCL mandibular resection, an FFF reconstruction and a bar on 4 implants. Clinical intraoral view without (C) and with prosthesis (D).

**FIGURE 9.** Patient no. 28: A, Panoramic view of a FFF mandibular reconstruction after LCL mandibular, inferior lip, and chin resections for a large squamous cell carcinoma. B, Clinical aspect after radiotherapy: the remaining orbicular muscle is bonded to the skin paddle. C, Two implants were placed in the anterior sector. Clinical aspect with the 2 prosthesis and closed lips. The skin paddle has reconstructed the anterior buccal floor and the cutaneous removed chin. Two buccal flaps were inserted to reconstruct mucosal part of the inferior lip. D, The cutaneous side of the inferior lip was reconstructed with pedicled Dufourmentel flap. E, Inferior lip height and vestibular groove permitted prosthesis placement and covering even during mouth opening. F, Clinical view after placement of 2 additional implants for stabilizing maxillary denture.
This work illustrates the surgical and prosthetic factors to take into account to provide high implant success rate. Implant-supported or implant-stabilized prostheses are the best choice for patients reconstructed by means of FFF because conventional prostheses with dental or mucosal stabilization are not possible. However, each patient is different, and it is necessary to take into account all the factors to achieve to best result in jaw reconstruction, leading to dental restoration.

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