Implant Stability Outcomes After Immediate and Delayed Revascularized Free Fibula Flaps: A Preliminary Comparative Study

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Purpose: This pilot study investigated the retrospective outcomes of implants placed immediately or with a delayed protocol in revascularized free fibula flaps (FFF). Materials and Methods: Patients undergoing FFF between 2014 and 2017 were included in the study. Implants were inserted either immediately or 23.63 ± 10.61 months after reconstructive surgery. Resonance frequency analyses were recorded at the time of implant placement (first control) and 4 months postoperatively while uncovering and screwing the gingiva formers (second control). The statistical significance level was set at P < .05. Results: Eight patients (four men, four women, mean age: 46.75 ± 12.96 years) were included in the study. Twenty-six implants were placed in FFF (14 immediate, 12 delayed), and 28 were placed in the alveolus. All implant stability quotient (ISQ) scores were in high stability ranges. Statistically significant differences were observed between delayed (79.25 ± 4.77) and immediate implant placement (73.14 ± 7.42) at first controls, but not at second controls (79.17 ± 3.59 and 76.00 ± 6.18). The ISQ values of immediate implant placement significantly increased from first to second controls (P = .018). Bicortically placed implants showed significantly higher scores than unicortical implants (P < .018). ISQ values of FFF and alveolar bone groups were similar (P > .05). Conclusion: High stability scores similar to alveolar bone could be achieved by both immediate and delayed implant placement. Bicortical implantation results in better implant stability. Int J Oral Maxillofac Implants 2018;33:1368–1373. doi: 10.11607/jomi.6725

Keywords: dental implant, implantation times, resonance frequency analyses, revascularized free fibula flap

In segmental defects of the jaws, revascularized free fibula flap (FFF) is one of the reconstructive options of choice.1–3 Following FFF surgery, dental rehabilitation has increasingly gathered attention and plays a crucial role in patients’ quality of life.4,5 However, dental rehabilitation of these patients is mostly challenging because of the excessive bone loss at the essential supporting tissues. Therefore, dental implants could be preferred as a treatment option, as they may provide sufficient support for a dental prosthesis.6,7 Also, dental rehabilitation with an implant-supported prosthesis improves esthetics and provides lip support as well as allowing the patient to masticate.8

Predictable results of dental implants placed in FFF have been reported for both simultaneous implant placement with FFF surgery and delayed implantation after complete recovery of the FFF.2,7–10 Despite these favorable results, there is limited evidence for the implications of the timing of implant placement.8 The main determinants of long-term success in dental implant procedures are the primary stability and secondary stability of the implant, which are essential in estimating the ideal recovery period and the consolidation period for the prosthetic stage.11 Implant stability is also a reliable prerequisite for the quality of osseointegration, and high primary stability is directly associated with secondary stability.12 Although several methods are being used to evaluate implant stabilization, resonance frequency analysis (RFA), which can

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also show the changes in bone-to-implant contact, has been used and has been reported to be a repeatable, practical, and reliable method.\textsuperscript{11,13} RFAs could indicate adequate implant stabilization and could suggest consolidation time and earlier loading of the implants. Because implant stability can show the level of osseointegration, investigating the changes of stability levels of implants placed simultaneously with the FFF surgery or after the FFF healing could provide useful data for timing of implant placement. Therefore, this pilot study aims to investigate the retrospective outcomes of implants placed immediately or with the delayed protocol in FFFs.

**MATERIALS AND METHODS**

Patients undergoing segmental resection and revascularized FFF at the University of Marmara hospital between 2014 and 2017 were included in the study. The University of Marmara Ethics Committee approved the study (no:09.2017.421). The study was performed according to the principles of the Declaration of Helsinki, and all patients had signed a consent form. All patients were treated with dental implants, and patients who came to the follow-ups during the treatment period were included in the study. Patients who smoke, patients with defects involving mandibular condyles, patients who had uncontrolled diabetes, patients on intravenous bisphosphonate therapy, and patients who had undergone chemotherapy or radiotherapy after dental implant placement were excluded. The demographic data, time of implant placement, and type of implant-bone anchorage were also recorded.

**Free Fibula Flap Reconstruction Surgery**

Preliminary standard clinical examination, computerized tomographic (CT) scans, panoramic evaluation, blood tests, study model, and cardiac and anesthesia consultations were performed for all patients. Extensive medical history was taken, angiographic evaluation of the legs was performed, and disease staging was evaluated for oncologic patients. The temporomandibular structures were spared in all cases. For the FFF reconstruction procedure, the two-team approach was performed, in which the jaw resection and preparation of the recipient bed and the harvesting of the graft were performed simultaneously. Before resection, a single 2.4-mm reconstruction plate was bent and fixed to the mandible extending to both sides of the segment planned for resection to ensure the recipient bone morphology and temporomandibular joint (TMJ) stability. Fibular flap harvest was performed under a leg tourniquet, and the flap was shaped according to the bone gap and pre-bent plate. The fibula was regularly placed at the lower border of the jaw, and at least two screws were inserted concerning the implant planning. The peroneal artery was anastomosed to either superior thyroid or facial arteries. Either facial or external jugular veins were anastomosed to the donor’s veins for venous drainage. None of the patients was taken to the intensive care unit (ICU) following surgery. All patients were hospitalized for 5 days and received intravenous (IV) ampicillin sulbactam 1 g 4 times daily (Duocid, Pfizer). During the hospitalization period, a clear liquid diet for 3 days was given, and then patients received a soft diet for 3 weeks. Skin sutures, if any, were removed at 7 to 10 days postoperatively.

**Implant Insertion and RFA Measurements**

Implants were performed as per the standard protocol of the manufacturer’s instructions, and the same clinician (F.C.) performed all dental implants (Ossean, Intra-Lock International). Implants were inserted either at the time of FFF surgery or 23.63 ± 10.61 months (10 to 33 months) after the FFF surgery. The location and number of the implants depended on a prosthetic treatment plan and bone condition. All implants were screw-shaped with 3.4 to 4.3 mm in diameter and 8 to 13 mm in length. All implants were left for submerged healing. Sutures were removed 7 to 10 days postoperatively.

All RFA measurements were made according to the manufacturer’s instructions, and the smart pegs were screwed onto the implants after the isolation of blood, saliva, and soft tissues by use of the plastic carriers. RFA measurements were performed with the Ostell Mentor (Integration Diagnostics) in three different directions (buccal, palatine/lingual, and mesial), and the average of the three values was recorded as the implant stability quotient (ISQ) value. The ISQ value ranges from 0 to 100 and is divided into three categories for in vivo investigations: low stability (< 60 ISQ), medium stability (60 to 70 ISQ), and high stability (> 70 ISQ).\textsuperscript{7} ISQ values were recorded at the time of implant placement (first control) and 4 months postoperatively while uncovering and screwing the gingiva formers (second control). If there were no mobility, implant-related pain, swelling, suppuration, discomfort, peri-implantitis, or ongoing pathologic processes, and if there was sufficient stability after the second control, patients were referred to the University of Yeditepe prosthetic department for rehabilitation.

**Statistical Analyses**

Statistical calculations were performed with Number Cruncher Statistical System 2007 Statistical Software program for Windows. Besides standard descriptive statistical calculations (mean and standard deviation),
an unpaired $t$ test was used for the comparison of groups, paired $t$ test was employed in the assessment of first and second measurement stability values, and Pearson’s correlation test was used to determine the relationships between the implants in the alveolus and FFF stability values. The statistical significance level was established at $P < .05$.

### RESULTS

Eight patients (four men and four women with a mean age of 46.75 ± 12.96 years; range: 26 to 63 years) were included in the study. Indications for FFF reconstruction were ameloblastic fibroma at the mandible (one patient), ameloblastoma at the mandible (two patients), firearm wounds at the mandible (two patients), giant cell granuloma at the mandible (one patient), osteosarcoma at the mandible (one patient), squamous cell carcinoma (SCC) at the maxilla (one patient). The osteosarcoma patient received only post-resection chemotherapy, and the SCC patient received both chemotherapy and radiotherapy before implant placement. Just one FFF was performed in the maxilla, and the rest were performed in the mandible. A total of 54 implants were inserted, of which 26 were placed in FFF and 28 were placed in the remaining alveolar bone (14 maxillae and 14 mandibles). The characteristics of the 26 implants placed in FFF are shown in Table 1.

All mean values of the measurements of the first and second control stability of dental implants in FFF and alveolar bone were shown in Table 2. It was observed that the mean values are found to be between high stability ranges for all assessments. The comparison of stability between the delayed and immediate implant placement procedures is shown in Table 3. The stability of the implants in the delayed protocol group was significantly higher than the immediate implantation group at first controls ($P = .022$); however, this was not the case for second controls ($P > .05$). The ISQ values of immediate implantation were significantly increased from first to second controls ($P = .018$). The implants placed in FFF with a bicortical anchorage showed significantly higher ISQ values than unicortically anchored implants for all assessments ($P < .05$) (Table 4). However, the ISQ values of implants in FFFs were not significantly different for both diameter (first control: $r = -.058$ and $P = .779$; second control: $r = -.221$ and $P = .332$) of the implants at all assessments. There was not any statistically significant difference observed for ISQ values between FFF and alveolar bone groups for all assessments (first control: $r = -.134$ and $P = .514$; second control: $r = -.205$ and $P = .335$).

One patient, at the immediate implantation group, showed signs of infection and swelling 1 month after the FFF surgery. CT scans showed that there was a split

### Table 1  Characteristics of Implants Placed in FFF

<table>
<thead>
<tr>
<th>Time of implantation</th>
<th>n (26)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delayed</td>
<td>12</td>
<td>46.15</td>
</tr>
<tr>
<td>Immediate</td>
<td>14</td>
<td>53.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of bone support</th>
<th>n (26)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicortical</td>
<td>14</td>
<td>53.85</td>
</tr>
<tr>
<td>Unicortical</td>
<td>12</td>
<td>46.15</td>
</tr>
</tbody>
</table>

### Table 2  Mean ISQ Values at First and Second Controls in Both FFF and Alveolar Bone

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Minimum</th>
<th>Maximum</th>
<th>ISQ (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First control</td>
<td>26</td>
<td>65</td>
<td>84</td>
<td>75.96 ± 6.95</td>
</tr>
<tr>
<td>Second control</td>
<td>24</td>
<td>69</td>
<td>83</td>
<td>77.58 ± 5.2</td>
</tr>
<tr>
<td>Alveolus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First control</td>
<td>28</td>
<td>67</td>
<td>74</td>
<td>71.93 ± 1.54</td>
</tr>
<tr>
<td>Second control</td>
<td>28</td>
<td>70</td>
<td>75</td>
<td>72.50 ± 1.17</td>
</tr>
</tbody>
</table>

### Table 3  Comparison of Stability Between the Delayed and Immediate Implantation Procedures

<table>
<thead>
<tr>
<th></th>
<th>Delayed (n = 12) (mean ± SD)</th>
<th>Immediate (n = 14) (mean ± SD)</th>
<th>$P^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFF first control</td>
<td>79.25 ± 4.77</td>
<td>73.14 ± 7.42</td>
<td>.022*</td>
</tr>
<tr>
<td>FFF second control</td>
<td>79.17 ± 3.59</td>
<td>76.00 ± 6.18</td>
<td>.139</td>
</tr>
</tbody>
</table>

$P = .891$ $P = .018*$

### Table 4  Comparison of Stability Between Bicortical and Unicortical Implants

<table>
<thead>
<tr>
<th></th>
<th>Bicortical (n = 14) (mean ± SD)</th>
<th>Unicortical (n = 12) (mean ± SD)</th>
<th>$P^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFF first control</td>
<td>81.29 ± 3.6</td>
<td>69.75 ± 4.03</td>
<td>.0001*</td>
</tr>
<tr>
<td>FFF second control</td>
<td>81.29 ± 2.02</td>
<td>72.4 ± 3.47</td>
<td>.0001*</td>
</tr>
</tbody>
</table>

$P = .999$ $P = .007*$

$P = \text{free fibula flap}$
fracture at the lateral side of the graft with close proximity to the posterior implants (Fig 1). Reentry to the graft area was performed, and both the fractured segment and two implants were removed. The medial wall of the graft was intact and showed no discontinuity. Therefore, the remaining FFF was left in position. No implants failed in the alveolar bone. The two implants’ failure led to a short time success rate of 92.6% for implants placed in FFF, and 100% for implants placed in the alveolar bone.

**DISCUSSION**

Oral rehabilitation with implants placed at FFF in patients undergoing jaw resections has shown encouraging outcomes in the recent literature. In this pilot study, the stability differences of implants placed in FFFs either immediately or with a delayed protocol were evaluated.

The success rate of implants placed in FFF was related to several factors such as radiotherapy, poor oral hygiene, lack of cooperation, patient’s healing potential, age, and diameter of implants. In the literature, the success rates were reported to be between 86% and 100%. It was also reported that success rates might decrease with time. In the study by Wu et al, while the success rate was 95% at 1 year, it was found to be 87% at 5 years. Similarly, Teoh et al reported 97%, 97%, and 79.9% at 1, 5, and 10 years, respectively. In addition, Jackson et al reported that implants inserted at FFF had similar survival rates to implants placed at native alveolar bone. Although it is still under debate, for proper analyses of the survival rate of implants, at least 5 years of follow-up is mandatory. Although long-term implant success results were not presented in this study, short-term success rates were 92.6% and 100% for FFF and alveolar bone groups, respectively, which was in line with previous reports.

The ideal time for implant placement is controversial for FFF procedures. While some authors suggest immediate implantation for FFF procedures, others support delayed implantation. Immediate implantation was endorsed because of reduced treatment time and theoretically similar success rates. However, it was also noted that patient selection is important when considering immediate implantation. Jackson et al reported that implantation time becomes more important when considering the decreased life expectancy of patients undergoing FFF procedures for oncologic reasons. On the contrary, other studies reported compromised bone viability due to the disturbed blood supply, lengthened operation time due to technical difficulties, or malpositioned implants with immediate implantation.

When delayed implant placement is planned, it should be preferred 6 to 12 months after the FFF procedure, so that muscle healing and bone modeling are completed. It was reported that with delayed implantation, there is time for acquiring good vascularization of the flap. Moreover, it was considered that bone remodeling is more critical during the first 6 months. In addition, for patients who received radiation therapy, delayed implantation should be the option of choice. In this study, two patients received adjuvant radiotherapy due to neoplastic lesions. Timing was chosen based on surgeon and patient preferences, such as the necessity of adjuvant radiotherapy due to neoplastic lesions, on an individual basis.

Although several methods have been used for measuring primary stability, RFA is reported to be the only method that can detect changes in different bone densities. In addition, it is a noninvasive instrument that allows both primary and secondary measurements of stability in vivo studies. In previous studies, removal torque analyses and RFA measurements showed the higher primary stability of FFF over other grafts. Furthermore, close bone-to-implant contact has been histologically confirmed 26 weeks after implant surgery. Although there were studies using RFA measurements for evaluating the implants placed at FFF procedures, the best of the authors’ knowledge, this is the first study in which the RFA measurements were used to target the stability differences of implants performed simultaneously or with the delayed protocol. In the present study, ISQ scores showed that high stability scores could be achieved with both immediate implantation and the delayed protocol. In addition, the present study population did not show any significant difference.
whether the implant was placed at FFF or alveolar bone. Moreover, it should be noted that the FFF group had slightly higher stability scores than the alveolar bone. This was probably a result of the cortical structure of fibula being denser than the alveolar bone.

In the present study, the delayed protocol had unexpectedly higher ISQ scores at the first control. However, at the second control, it was interestingly observed that, while the stability of immediately placed implants was significantly increased, the stability of implants placed after healing of FFF did not. Thus, the ISQ values had no significant difference for er, the bone-to-implant contact is higher at the implant bone-to-implant contact surface.32 In addition, better implants were placed bicortically, which allows a larger cortical thickness leads to better implant success if the dense bicortical structure of the fibula with a greater mary stability of the implants. It was reported that the needed.

Bone density is the main factor regarding the primary stability of the implants. It was reported that the dense bicortical structure of the fibula with a greater cortical thickness leads to better implant success if the implants were placed bicortically, which allows a larger bone-to-implant contact surface.32 In addition, better results could be achieved with longer implants due to bicortical anchorage.33 Sozzi et al reported that because the central marrow has a poor chance of participating in osseointegration, the success rate increases with bicortical or even tricortical placement.10 However, the bone-to-implant contact is higher at the implant neck.34 The ISQ values had no significant difference for both the diameter or the length of the implants. However, following previous studies, bicortically placed implants showed the most excellent ISQ scores, and their stabilities were significantly higher than that of implants with a unicortical anchorage, which indicated that for better stability, cortical support should be achieved as much as possible.

No flap failures were observed in the present study. However, one patient was referred back with a split FFF fracture in the immediate implantation group. This fracture caused the only two implant failures of this pilot study. After the removal of loosened implants and fractured bone, it was observed that the remaining medial cortical wall was intact and did not lose its stability. Therefore, the graft was left at its position. The patient was instead rehabilitated with removable dentures. The authors thought that split fracture could be a combination of several factors. First, the use of a final bur with a diameter smaller than that of the implant was proposed for achieving better primary stability at native bone.35 However, alveolar bone is more resilient than the fibula, so using burs with a smaller dimension would probably generate an extending stress at the fibula. Furthermore, the implant osteotomies of this pilot study were performed using the recommended final bur of the manufacturer. However, it is known that the final burs could still be slightly narrower than the fitting implant diameter, and might be generating extending stress, which might cause total splitting or greenstick fractures, mainly when the implant was bicortically anchored. Second, the unicortical insertion of the miniscrews, which was seen in computed tomography (CT) images, might be another stress-generating factor for increasing the splitting risk. Finally, the fibula is evolved for enduring vertical forces while it is in its original place, such as when the person is standing. However, when it is placed in the jaws, the forces have become horizontal, and the horizontal stress might decrease the force-bearing capacity of the fibula. Thus, the authors believe additional insertions with the final bur together with the bicortical insertion of the screws could decrease the extending stress and lower the risk of splitting. Conducting further studies for understanding the stress distribution caused by dental implants at FFF is necessary.

Low implant height is one of the most common causes of implant failures.17 Some authors suggested double barrel technique, distraction osteogenesis,17 aligning the FFF with the alveolar crest, and an onlay bone graft with FFF for achieving better esthetic results and better implant length and related stability.36,37 In the present study, all FFFs were plated to the lower border of the mandible. Although this resulted in a disharmony between the FFF and native height of the mandible, the patients had good facial contour as well as acceptable implant heights between 8 and 13 mm.

There are some limitations in this study. First, the low number of patients caused a limitation. Second, being a retrospective structure other than a randomized trial might cause a limitation. The treatment modalities were selected for individual basis instead of a randomization process. Therefore, there is a risk of patient selection bias regarding who had immediate implantation and who did not.

CONCLUSIONS

The findings of this pilot study showed that high stability scores similar to native alveolar bone could be achieved by both immediate and delayed implantation. In addition, the authors thought that bicortical implantation is the key factor for achieving better implant stability at FFF procedures; however, splitting risk of the FFF should not be underestimated. Further studies are needed to make firm conclusions.
ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

REFERENCES