Analysis of Dental Implant Rehabilitation in the Reconstructed Jaw by Deep Circumflex Iliac Artery Flap, a Retrospective Study

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Featured Application: Reconstruction by deep circumflex iliac artery flap is predictable for rehabilitation of oral function and aesthetics using implants by reproducing the shape of the jawbone and providing sufficient bone quantity and quality.

Abstract: The purpose of this study is to analyze the clinical results of the implant rehabilitation for a jaw reconstructed by the deep circumflex iliac artery (DCIA) flap. A total of 13 patients were included in this study from 2010 to 2020. Medical records were collected retrospectively and analyzed. The mandible was involved in 10 cases and the maxilla was in 3 cases. The average width of the DCIA flap was 8.6 mm, and the height was 20.65 mm. A total of 41 dental implants with a diameter of 3.9–5.0 mm and a length of 10.0–11.5 mm were placed at an average of 12.3 months after the reconstruction. The average follow-up period after delivering a permanent prosthesis was 15 months (range, 2 to 51 months) and the overall mean follow-up period was 48 months. In all, 3 implants of the total 41 implants were removed. The DCIA flap is the most suitable for reproducing the original contour of the original jawbone compared with the fibular flap. In addition, the height and width of the reconstructed bone is appropriate for implant placement, which is advantageous for the rehabilitation of oral function and aesthetics using the implant.

Keywords: maxilla-mandibular reconstruction; dental implant; deep circumflex iliac artery flap; microsurgical free flaps; bone resorption

1. Introduction

Large bone defects after a resection, caused by tumor, trauma or osteonecrosis, can occur anywhere on the oral and maxillofacial area [1–3]. After resection of the lesion, large bone defects can cause facial deformity, malocclusion, and dysfunction such as speech and swallowing. Loss of the alveolar and jaw bone can lead to significant masticatory impairment, so reconstruction requires recovery of the original shape and rehabilitation of original function [4,5].

The reconstruction must not only satisfy functional and esthetic recovery, but also provide sufficient bone volume to place the dental implant [6]. In patients who have undergone a resection of the jaw bone, reconstruction through free vascularized bone grafts with implant placement is regarded as the best treatment to restore function.

For the dental rehabilitation of the reconstructed bone, a dental implant was mainly used. Implant success was defined as an implant being comfortable to the patient and functionally supporting a prosthesis [7]. Primary implant stability is the most important feature for implant survival and success during implant installation. Primary stability depends on the bone quantity and quality, implant design, and the surgical technique [8].

Non-vascularized bone grafts are appropriate for small defects. However, microvascular-free flaps are mainly used for the reconstruction of large bone defects. The resorption rate of the
reconstructed bone by microvascular-free flaps is low, so the volume of the bone is maintained compared to non-vascularized bone grafts [9–11]. For the reconstruction of the jaw, various vascularized bone grafts have been used, such as fibular, scapular and iliac bone, and dental rehabilitation carried out by implant prosthesis after stabilization of the transplanted bone segment [12,13]. Vascularized bone grafts from the deep circumflex iliac artery (DCIA) and the fibula are frequently used for the reconstruction of defects of the mandible and maxilla [14,15].

For the comparison of the peri-implant bone resorption between the fibular and the DCIA flaps, there was no significant difference between the two flaps and there may not be a factor that determines the donor site selection [9]. The major benefits of the DCIA flap is the sufficient length and height of the grafted bone and that it is similar to the original contour of the mandibular arch. In addition, the DCIA flap is a vascularized bone graft with a lower bone resorption compared to a non-vascularized bone graft, so it is advantageous for maintenance after implant placement [10].

Recently, implant rehabilitation of the reconstructed jaw with the DCIA flap is popular. However, there are limited articles of long-term stability of dental implants. This study has great significance in that it has provided clinical results of the implantation of the reconstructed jaw.

The aim of this study was to analyze the clinical results that placed dental implants after maxillary or mandibular reconstruction by the DCIA flap.

2. Materials and Methods

2.1. Study Participants

The 13 patients who had large defects after resection of the jawbone and underwent reconstruction with the DCIA flap and implant-supported rehabilitation between 2010 and 2020 were analyzed. Medical records of the location of the lesion, operation procedure, the width and height of the flap, the follow-up period until implant placement, the number of implants, the diameter and length of the implants, the period for osseointegration, the total follow-up period, and the implant survival were investigated. We followed the Helsinki Declaration throughout this study. We obtained approval from the Chosun University Institutional Review Board (2-1041055-AB-N-01-2019-08).

2.2. Placement of the Dental Implants

In this study, patients with microvascular bone reconstruction were analyzed for the bone height and the width for the dental implant placement. All patients had been reconstructed with the DCIA flap and the implant surgery was performed after bone healing without recurrence. Following six months after implant surgery, the patients were delivered the implant-fixed prosthesis (Figures 1 and 2).

Dental Implants were placed an average of 12.3 months after reconstructive surgery. The number and location of the implant placement depended on the bone condition and the prosthetic plan. A total of 41 implants were placed. Osstem (TSIII SA, OSSTEM IMPLANT Co., Ltd., Seoul, Korea), Dentis (OneQ, HA, DENTIS Co., Ltd., Daegu, Korea), DIO (UF, DIO IMPLANT Co., Ltd., Busan, Korea), and NEO (IS III, NEOIMPLANT Co., Ltd., Seoul, Korea) implants were used. Among 41 implants, 14 implants were placed in a one-stage surgical approach and 27 implants were placed in a two-stage surgical approach.
Figure 1. Clinical photos of case, A 59-year-old woman was diagnosed with squamous cell carcinoma on left mandible (#36–38), and segmental mandibulectomy was performed, and two implants were installed by computer-guided implant surgery. (a) Pre-operative intra-oral photo. (b) Post operative intra-oral photo after 1 month. (c) Mucosal healing was competed at 1 years’ intra-oral photo. (d) Computer-based implant guided was applied for implant placement. (e) Connect the healing abutment and vestibuloplasty was performed. (f) Screw-type implant prosthesis was delivered.

2.3. Data Collection

For evaluation of dental implant, digital panoramic radiographs (PLANMECA Promax 2D, Helsinki, Finland), CT radiographs (PLANMECA Viso G7, Helsinki, Finland) were taken and images were obtained using PACS software (INFINITT, INFINITT Healthcare Co., Ltd., Seoul, Korea). Actual implant length was used for calibration. The dimensional distortion between the different panoramic radiographs was corrected with the actual implant dimensions. One observer performed all measurements five times. The mean value of these five measurements was used for the analysis to account for data variation. The graft bone’s transverse width and height were measured on CT data at the mid-central portion of the grafted bone. Peri-implant bone loss (Distance; D) was recorded by comparing panoramic radiographs immediately after implant placement (T0), at the time of impression taking for a prosthesis (T1), and 6–12 months after the prosthesis (T2). The crown-implant ratio was calculated after the measurement of the height of the prosthesis and the implant length.
## 3. Results

### 3.1. Patients Characteristics

The age of the patients at the time of resection of the jawbone ranged from 15 to 75 years, with a mean age of 58 years. Seven patients were male and six patients were female. Information concerning the patient’s characteristics and the indication for reconstruction are shown in Table 1. In most cases ($n = 7$) the patients underwent reconstruction due to squamous cell carcinoma, osteomyelitis ($n = 2$), mucoepidermoid carcinoma ($n = 1$), verrucous carcinoma ($n = 1$), chondrosarcoma ($n = 1$), and peripheral ossifying fibroma ($n = 1$).
Table 1. Patients characteristics.

| Patients Number | Age | Gender | Diagnosis | Site | Operation Procedure | Timing of Reconstruction | Overall F/U Period (Month) | Implant Placement (One or Two-Stage) (Month) | F/U Period after Prosthesis (Month) |
|-----------------|-----|--------|-----------|------|---------------------|--------------------------|---------------------------|-------------------------------------------|-----------------------------------|
| #1              | 68  | M      | SCC       | Mn (#35–45) | MM | Primary             | 107                      | 10                                       | 51                               |
| #2              | 63  | M      | SCC       | Mn (#35–38) | MM | Primary             | 96                       | 10                                       | 2                                |
| #3              | 59  | F      | SCC       | Mn (#36–38) | SM | Primary             | 44                       | 10                                       | 27                               |
| #4              | 15  | F      | MC        | Mx (#14–18) | PM | Primary             | 43                       | 10                                       | 11                               |
| #5              | 51  | M      | VC        | Mn (#43–48) | SM | Primary             | 29                       | 11.5                                    | 7                                |
| #6              | 71  | F      | SCC       | Mn (#34–38) | MM | Primary             | 63                       | 10                                       | 8                                |
| #7              | 75  | M      | SCC       | Mn (#33–36) | SM | Primary             | 44                       | 9                                        | 31                               |
| #8              | 69  | M      | SCC       | Mn (#35–37) | SM | Primary             | 32                       | 13                                       | 10                               |
| #9              | 62  | F      | OM        | Mn (#33–34) | S  | Primary             | 43                       | 34                                       | 3                                |
| #10             | 66  | F      | CS        | Mn (#33–34) | SM | Primary             | 41                       | 6                                        | 16                               |
| #11             | 41  | F      | PO        | Mx (#14–16) | PM | Secondary           | 17                       | 10                                       | 7                                |
| #12             | 53  | M      | SCC       | Mn (#43–46) | SM | Primary             | 38                       | 14                                       | 16                               |
| #13             | 69  | M      | OM        | Mx (#21–26) | S  | Primary             | 28                       | 13                                       | 6                                |

SCC, squamous cell carcinoma; MC, mucoepidermoid carcinoma; VC, verrucous carcinoma; OM, osteomyelitis; CS, chondrosarcoma; PO, peripheral osteoblastoma; Mn, mandible; Mx, maxilla; MM, marginal mandibulectomy; SM, segmental mandibulectomy; PM, partial maxillectomy; S, sequestrectomy.

The site of resection was mandible in most cases (n = 10), and maxilla (n = 3). Five patients received a segmental mandibulectomy, four patients received a marginal mandibulectomy, two patients received a sequestrectomy, and two patients received a partial maxillectomy. The reconstruction with a DCIA flap was performed simultaneously with the resection of the jawbone in 12 patients. One patient underwent reconstruction after 8 months.

The median total follow-up period after reconstruction was 48 months, ranging from 17 to 107 months. The implants were placed after a mean of 12.3 months (6–34 months) after reconstruction. The average interval between the first and second stage implant surgery was 2.8 months, ranging from 0 to 6 months. The average follow-up period after fixing a permanent prosthesis was 15 months, ranging from 2 to 51 months (Table 1).

3.2. Analysis of Implants

A total of 41 implants were placed in 13 patients. Implants with a diameter of 3.9–5.0 mm and length of 10.0–11.5 mm were used. In all, 3 of the total 41 implants were removed. No bone loss was observed around the three implants removed. One implant was removed due to peri-mucositis with gingival swelling, and two were removed at the request of the patient. The mean crown-implant (C/I) ratio was 1.26 ranging from 0.69 to 1.83. Two implants were excluded from the ratio analysis because the prosthesis was not completed (Table 2).

Table 2. Implant analysis.

| Patients Number | Numbers/Type of Implants | Implantation Area | Diameter of Implants (mm) | Length of Implants (mm) | Crown-Implant Ratio | Implant Failure (n) |
|-----------------|--------------------------|-------------------|---------------------------|------------------------|---------------------|---------------------|
| #1              | 4/Dentis HA             | #34, 35, 44, 45   | 4.3/4.3/4.3/4.3          | 10.0/10.0/10.0/10.0    | 1.15/1.18/1.22/1.31  | 0                   |
| #2              | 2/DF/D UF              | #35, 36           | 4.0/4.0                  | 10/10                  | 0.91/0.91           | 0                   |
| #3              | 2/NEO                   | #36, 37           | 4.5/5.0                  | 10/10                  | 1.21/0.97          | 0                   |
| #4              | 3/DF/D UF              | #14, 15, 16       | 4.0/4.0/4.5              | 10/10/10              | 1.29/1.36/1.20      | 0                   |
| #5              | 3/DF/D UF              | #43, 44, 46       | 4.0/4.0/4.5              | 11.5/11.5/10          | 0.88/0.70/0.98      | 1                   |
| #6              | 4/Dentis oneQ           | #34, 35, 36, 37   | 4.2/4.2/4.2/4.2          | 10/10/10/10           | 0.90/0.69/-/-       | 0                   |
| #7              | 4/Ostern TS             | #33, 34, 35, 36   | 4.0/4.0/4.0/4.0          | 10/10/10/10           | 1.83/1.82/1.83/1.83 | 0                   |
| #8              | 3/DF/D UF              | #35, 36, 37       | 4.5/5.0/5.0              | 10/10/10              | 1.35/1.29/1.18      | 0                   |
| #9              | 2/Dentis oneQ           | #33, 34           | 4.2/4.2                  | 10/10                  | 1.16/1.12          | 0                   |
| #10             | 3/Dentis oneQ           | #34, 35, 37       | 3.9/4.2/4.2              | 10/10/10              | 1.60/1.52/1.43      | 0                   |
| #11             | 3/Dentis oneQ           | #14, 15, 16       | 4.2/4.7/4.7              | 10/10/10              | 1.03/1.05/0.98      | 0                   |
| #12             | 4/DF/D UF              | #43, 44, 45, 46   | 4.2/4.2/4.2/4.7          | 10/10/10/10           | 1.65/1.86/1.77/1.33 | 0                   |
| #13             | 4/DF/D UF              | #21, 22, 24, 26   | 4.5/5.0/5.0/5.0          | 10/10/10/10           | 1.10/1.14/1.10/1.19 | 0                   |

3.3. Evaluation of Peri-Implant Marginal Bone Loss

The marginal bone loss at the time of taking an impression for a prosthesis (T1), and 12 months after the prosthesis (T2), was measured based on the time immediately after implant placement (T0). At the time of T1, the marginal bone loss of 41 implants was measured, and the marginal bone loss of 36 implants with the final prosthesis at the time of T2. In T1, marginal bone loss was observed to be an average of 0.16 mm compared to T0,
and in T2, marginal bone loss (D) was observed to be an average of 0.48 mm compared to T0 (Table 3).

**Table 3. Marginal bone loss.**

| Timepoint | Number of Implants | Differences to T0 (Mean ± SD) |
|-----------|--------------------|-----------------------------|
| T1        | 41                 | 0.16 ± 0.34                 |
| T2        | 36                 | 0.48 ± 0.48                 |

T0, immediately after implant placement; T1, at the time of impression taking for a prosthesis; T2, 12 months after the prosthesis.

### 3.4. Volume of Grafted Bone

All grafted bones had sufficient vertical and horizontal dimension for the placement of the dental implants. The average width of the flap was 8.61 mm, the height was 20.65 mm, and the coronal width was 46.91 mm. The mean of the minimum sagittal width of grafted bone was 7.09 mm and the mean of the maximum was 10.87 mm (Table 4).

**Table 4. Graft bone sagittal minimum and maximum width (mm).**

| Patients Number | Graft Bone Sagittal Minimum Width (mm) | Graft Bone Sagittal Maximum Width (mm) | Average between Minimum and Maximum (mm) |
|-----------------|----------------------------------------|----------------------------------------|------------------------------------------|
| #1              | 6.92                                   | 12.27                                  | 9.60                                     |
| #2              | 6.24                                   | 8.03                                   | 7.14                                     |
| #3              | 7.04                                   | 9.17                                   | 8.11                                     |
| #4              | 5.51                                   | 12.60                                  | 9.06                                     |
| #5              | 9.31                                   | 11.30                                  | 10.31                                    |
| #6              | 5.25                                   | 7.95                                   | 6.60                                     |
| #7              | 6.59                                   | 9.12                                   | 7.86                                     |
| #8              | 10.27                                  | 13.23                                  | 11.75                                    |
| #9              | 6.11                                   | 8.67                                   | 7.39                                     |
| #10             | 5.80                                   | 13.54                                  | 9.67                                     |
| #11             | 8.4                                    | 10.6                                   | 9.50                                     |
| #12             | 8.95                                   | 15.31                                  | 12.13                                    |
| #13             | 5.77                                   | 9.46                                   | 7.62                                     |
| Mean ± SD      | 7.09 ± 1.62                            | 10.87 ± 2.36                           | 8.46 ± 1.73                              |

Bone grafts from the DCIA were sufficient to retain regular-sized and longer implants, with height ranging from 10.12 to 33.23 mm and width ranging from 5.82 to 10.83 mm (Table 5).

**Table 5. Height, crestal width, mesiodistal length of the grafted bone (mm).**

| Patients Number | Height (mm) | Crestal Width (mm) | Mesiodistal Length (mm) |
|-----------------|-------------|--------------------|-------------------------|
| #1              | 27.19       | 7.79               | 66.41                   |
| #2              | 10.12       | 7.56               | 45.85                   |
| #3              | 18.82       | 7.7                | 46.10                   |
| #4              | 16.88       | 8.46               | 37.02                   |
| #5              | 11.25       | 9.39               | 31.13                   |
| #6              | 10.78       | 7.05               | 42.09                   |
| #7              | 28.71       | 8.79               | 63.20                   |
| #8              | 18.05       | 10.83              | 37.37                   |
| #10             | 21.04       | 8.74               | 36.22                   |
| #11             | 5.82        | 9.29               | 82.95                   |
| #12             | 33.23       | 10.4               | 55.44                   |
| #13             | 21.34       | 10.2               | 38.22                   |
| Mean ± SD      | 20.65 ± 7.51| 8.61 ± 1.43        | 46.91 ± 15.89           |

### 3.5. Implant Survival

During the follow-up, failure was observed in one implant (2.4%) with a survival rate of 97.6% (Table 6). Two implants were removed at the patient’s request. One of the three implants was removed in the patient treated for a verrucous carcinoma. In the other patients, all of implants were maintained successfully.
Table 6. Implant survival.

| No. of Patients | No. of Placement Implants | No. of Removed Implants | Survival Rate |
|-----------------|---------------------------|-------------------------|---------------|
| 13              | 41                        | 1                       | 97.6%         |

4. Discussion

The decision as to which donor site would be chosen for the reconstruction depended on the bone defect size and location [10]. The DCIA flap bone’s vertical volume is much greater, allowing for the reconstruction to have the original height of the mandible. Additionally, the implant placement can be performed without creating unfavorable implant-to-crown ratios [10].

The DCIA flap has been demonstrated to be very reliable for the reconstruction of maxillo-mandibular complex defects following the ablation of lesions. The DCIA flap offers optimal bone shape for maxilla reconstruction, which could form a facial bone buttress or orbital rim. It is also important to be able to make a curvature for mandibular reconstruction. In the DCIA flap, the anterior superior iliac spine is similar to the angle of the jaw, the anterior inferior iliac spine is similar to the head of the condyle, and the iliac crest is similar to the lower border of the mandible. Thus, the DCIA flap, which provides advantages for the reconstruction of the maxillo-mandibular complex, has become the flap of choice [16].

The DCIA flap provides a large amount of tissue compared with other flaps [16]. The DCIA flap has favorable bone height and width for implant placement, compared with the fibular flap, allowing for the reconstruction to have the original bone height of the maxillo-mandibular complex. The fibular flap can be applied, which needs the long bone segment for the reconstruction of the mandible. One of the disadvantage of the fibular flap is the small diameter of the grafted bone. In edentulous patients with defects in the mandible, the graft bone height might be sufficient to reconstruct the alveolar bone ridge and support facial contour. However, vertical discrepancies were observed between the teeth bearing and the grafted fibula [10,17]. In some studies, the microvascular fibular flap was validated as a recipient site for dental implants [18]. In several studies, a lack of vestibular and granular soft tissue at the implant site was observed due to an abnormal occlusal relationship between the maxilla and mandible after mandibular reconstruction, a vertical discrepancy between the grafted and teeth bearing areas, and a lack of keratinized tissue [19]. Furthermore, the retention of implants can be difficult because of the limited graft bone height [10]. This allows the surgeon to determine the height and width of the bone component [16].

After the reconstruction by the DCIA flap, implant placement can be performed without creating unfavorable crown-implant ratios [14]. An early study demonstrated that the C/I ratio was a more sensitive indicator of implant failure than the residual bone height [20]. Accordingly, a C/I ratio between 0.5 and 1 was proposed for the prevention of peri-implant bone stress, marginal bone loss, and eventual implant failure [21–23]. Conversely, another study reported that the C/I ratio of 889 single tooth implants was 1.3 on average [24].

In this study, it was confirmed that the crown to implant ratio was 1.26, which was close to the ideal ratio suggested in the previous study. Of the 41 implants placed in 13 patients in this study, 39 implants excluding 2 implants were followed up continuously through radiologic examination after the final prosthesis. Of the 39 implants that completed the final prosthesis, marginal bone loss was not observed. One implant showed the soft tissue swelling around the implant. Implant success was defined in implantology as follows: no pain, mobility, peri-implant radiolucency. For implant success, peripheral bone loss for the first year should be less than 1 mm and should subsequently be no more than 0.2 mm [25,26]. In this study, all of the 39 implants showed no sign of peripheral bone loss, but peripheral gingival swelling and pain were observed. The corresponding implants were removed due to the risk of peri-implant mucositis.
When using the DCIA flap, generally soft tissue is reconstructed with the internal oblique muscle, so that the soft tissue has a larger volume than the original gingiva. Moreover, they are not fixed to the bone by the periosteum, and they generally do not allow the reconstruction of the vestibule. From the point of view of the soft tissue to retain the implant, flap thinning and vestibular shaping are often required [27]. Except for the crown-root ratio, another reason for implant failure is that the axis of the implant is not always the same as the axis of the prosthesis, which can induce torque forces. To reduce this risk, the use of surgical guides minimizes the angle between the prosthetic axis and the implant axis and allows for accuracy of rehabilitation [28,29].

In patients reconstructed using the DCIA flap, the crown-implant ratio, which is important for implant retention, was also confirmed to be close to the ideal value. In addition, marginal bone loss was minimum in this study. However, there was a limitation in that there were insufficient investigations on soft tissues thickness and condition, which are important for implant retention, and that the number of patients to be investigated was limited. In this study, we have focused on the hard tissue and the implant survival rate. Although the implant has no problem in radiologic examinations, the patient had a potential to suffer from peri-implant mucositis and shallow vestibular depth by thick and movable soft tissue around the implant. Accordingly, further studied of soft tissue evaluation and management is needed in the future.

5. Conclusions

The deep circumflex iliac artery flap is the most suitable flap for reproducing the original contour of the jaw bone. In addition, the height and width of the reconstructed bone are suitable for implant placement, which is advantageous for the dental rehabilitation and esthetic reconstruction for maxilla-mandibular defects.

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