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Sequential evaluation for bone union of transferred fibula flaps in reconstructed mandibles: panoramic X-ray versus computed tomography

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Abstract. The purpose of this study was to sequentially evaluate bone union of fibular grafts in mandibular reconstruction. Patients who underwent routine follow-up computed tomography (CT) and panoramic X-ray imaging during a period of ≥2 years were enrolled. On panoramic X-ray images, bone union was scored as 0 (absent callus formation) or 1 (complete callus formation). On CT images, a scale of 0 to 2 was used (0, absent callus formation; 1, complete callus formation only on the labial side; 2, complete callus formation on both the labial and lingual side). A total of 56 bone junctions were evaluated in 20 patients. Five of 56 junctions (9%) in four of 20 patients (20%) showed radiological non-union (panoramic X-ray score = 0, CT score = 0 or 1) at 2 years after surgery. All bone junctions with radiological non-union were located at the mandibular angle. No categorical values, including diabetes mellitus and radiation therapy, were significantly associated with radiological non-union. In conclusion, assessing at least two sides (i.e. labial and lingual sides) on CT images is adequate to evaluate bone union in transferred fibula flaps. Careful fixation at the mandibular angle may improve the rate of bone union.

Key words: free fibula osteocutaneous flap; mandibulectomy; bone union; panoramic X-ray; computed tomography.

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Since their introduction by Taylor et al.[1] and their use in composite reconstruction of the mandible and oral soft tissues by Hidalgo,[2] free fibula osteocutaneous flaps have become the 'workhorse' for head and neck reconstruction.[3] Currently, the most common indication for free fibula osteocutaneous flap transfer is mandibular reconstruction after tumour resection, such as segmental mandibulectomy. Good bone union is necessary to allow timely post-operative radiation therapy after cancer resection.[4] Dental rehabilitation with osseointegrated implants in reconstructed mandibles contributes to the restoration of

both function and aesthetics.[5] Good bone union is also essential for dental implant placement and prosthesis use in reconstructed mandibles.[6,7]

Disa et al., in a study with a mean follow-up period of 54 months, reported a bone union rate of 93% in fibulae transferred for mandibular reconstruction, based on panoramic radiographs.[7] Osseous flaps, including fibula, radius, scapula, and ilium, had a bone union rate of 97% in another study with a mean follow-up period of 47 months.[6] A recent study reported radiological non-union in 20% of neomandibles at the time of computed tomography (CT) evaluation (mean follow-up 15 months).[8]

Another study found that panoramic radiographs alone were not sufficient for comprehensive evaluation of the entire bone segment of transferred fibulae in mandibular reconstruction. Therefore, three-dimensional CT scans were used in that study to visualize variations in bone union of fibula free flaps.[4]

The purpose of this study was to sequentially evaluate long-term (≥2 years postoperatively) bone union of transferred fibula flaps in mandibular reconstruction, and to determine adequate methods for evaluating bone union in neomandibles by comparing radiological findings on panoramic X-ray and CT.

Materials and methods

This was a retrospective study of patients who underwent free fibula osteocutaneous flap transfer at Kobe University Hospital between October 2010 and January 2013. All fibulae used in mandibular reconstruction were covered in periosteum, with additional periosteum from the donor site present at both ends.[4] Transferred fibulae were positioned in alignment with the lower border of the residual mandible as a mono-barrel graft. To restore facial contour, fibular osteotomies were performed only at the 'T' and 'A' positions, described in detail below (Fig. 1). Small gaps between bones at 'T' or 'A' were filled with free bone chips obtained from the resected fibula (Fig. 1).

Patients who underwent routine follow-up CT and panoramic X-ray imaging during a period of ≥2 years after surgery to monitor for tumour recurrence or to confirm plate fixation, and who did not have early tumour recurrence, were enrolled. CT examinations were performed with an Aquilion 64 CT scanner (Toshiba Medical Systems, Tokyo, Japan) at the Hakubikai Imaging Support Centre or at Kobe University Hospital (tube current 100 mA, scanning time 3 s, slice thickness 2 mm, slice width 2 mm, field of view 25 cm). Evaluations of bone union were performed based on the bone condition on CT images.

All patients provided informed consent for the use of CT and panoramic X-ray images for this study. This study was exempted from the need for ethical approval by the institutional medical ethics committee because of its retrospective nature. The study was performed in accordance with the Declaration of Helsinki.

Medical records were reviewed to determine patient age, sex, underlying disease, the presence of diabetes mellitus, preoperative or postoperative radiation therapy, chemotherapy, fixation hardware, extent of mandibular defects, and time to resumption of oral intake. Mandibulectomy defects were classified according to the four points on the mandible where curvatures are greatest (i.e. the lines along the longitudinal axes of the right and left mental tubercle (T, T′) and the mandibular angles (A, A′)) and the condyle (C, C′).[9] This method has been described previously as the 'CAT classification'.[10–12] Defects that included neither the mandibular angle (A) nor the mental tubercle (T) were defined as defects of the 'body' (Fig. 1).

Evaluation of bone union

Three independent clinicians evaluated bone union in terms of osseous callus formation. Panoramic X-ray images were assigned a score of 0 or 1, where 0 represents absent callus formation and 1 represents complete callus formation (Fig. 1). In the evaluation of CT images, a scale of 0 to 2 was used as follows: 0, absent callus formation; 1, complete callus formation only on the labial side; and 2, complete callus formation on both the labial and lingual side (Fig. 2).

Statistical analysis

Fisher's exact test was used to identify significant associations among categorical values, such as diabetes mellitus, smoking, alcohol consumption, radiation therapy, location ('body', 'T', or 'A'), type of bone junction (fibula to mandible, or fibula to fibula), and type of fixation hardware (reconstruction plate or miniplate). The data were analyzed with SPSS software package version 19 (IBM Corp., New York, NY, USA); values of $P < 0.05$ were considered statistically significant.

Results

Postoperative CT images and panoramic X-rays of 20 patients (10 men, 10 women; median age 67.2 years, range 54–83 years) were analyzed. Fifteen patients had undergone primary reconstruction after mandibulectomy for tumour ablation. Tumour types included squamous cell carcinoma ($n = 10$), ameloblastoma ($n = 3$), mucoepidermoid carcinoma ($n = 1$), and ameloblastic carcinoma ($n = 1$). Fracture or exposure of a mandibular reconstruction plate necessitated free fibula osteocutaneous flap transfer in five patients.

Seven of the 20 patients had diabetes mellitus. Radiation therapy was performed in two patients preoperatively and in five postoperatively. Three of the 20 patients received postoperative adjuvant chemotherapy.

Mandibulectomy defects according to the CAT classification were 'body' in six patients, 'AT' in six patients, 'T' in three patients, 'TT' in three patients, 'ATTA' in one patient, and 'A' in one patient. The flap pedicle was anastomosed with the facial artery in seven patients, with the superior thyroid artery in six, with the external carotid artery in three, with the transverse cervical artery in two, with the lingual artery in one, and with the occipital artery in one. The flap pedicle was anastomosed with the external jugular vein in eight patients, with the facial vein in six, with the internal jugular vein in three, and with the occipital vein in two. In one patient, the flap was anastomosed with the external jugular vein and the middle thyroid vein. Fixation hardware comprised miniplates in 18 patients and reconstruction plates in two. The median time to the resumption of oral intake after surgery was 8 days (range 6–43 days); the median time to mastication was 25.5 days (range 12–210 days).

A total of 56 bone junctions were evaluated in the 20 patients. There were 40 fibula-to-mandible junctions and 16 fibula-to-fibula junctions. Sequential bone union rates, as evaluated on panoramic X-rays and CT images, are shown in Fig. 3. Two years after surgery, five of 56 junctions (9%) in four of 20 patients (20%) showed radiological non-union (panoramic X-ray score = 0, CT score = 0 or 1). All cases of radiological non-union were at the 'A' location. Four of the non-unions were fibula-to-mandible junctions and one was fibula-to-fibula. None of the categorical values was significantly associated with radiological non-union (diabetes mellitus, $P = 0.10$; radiation therapy, $P = 1$; type of plate, $P = 0.34$; smoking,