Mandibular Reconstruction with Free Vascularized Fibular Graft

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Abstract

An iliac block graft is the most commonly used biomaterial for reconstruction following resection of the mandible. Its use has some disadvantages, however, including limitations on the amount of bone that may be harvested, and the subsequent increase in burden on the iliac bone. Therefore, recently, free vascularized fibular grafts have been used as an alternative in some cases. Here, we report the advantages of, and issues related to reconstruction using free vascularized fibular grafts observed at Tokyo Dental College Chiba Hospital. Eight patients undergoing mandibular reconstruction using free vascularized fibular grafts between January 2003 and January 2017 were investigated. Of these, 6 were men, and 2 were women. Age ranged from 38 to 74 years (average, 54 years). Primary diseases comprised malignant tumor in 3 patients, benign tumor in 3, and radiation osteomyelitis of the mandible in 2. The defects were classified as follows according to the CAT system (Condylar Head, Mandibular Angle, Mental Tubercle): 3 cases of Body, 2 of AT, and 1 case each of TT, ATTA, and CATT. The resection range of the mandible was 5–16 cm (average, 10 cm). The single barrel technique was used in 7 cases, and the double barrel technique in 1. In terms of the flap survival ratio, complete engraftment was achieved in 6 out of the 8 cases. Two cases of radiation osteomyelitis of the mandible, with necrosis caused by vascular breakdown after wound infection, were observed, however. While the advantages of mandibular reconstruction by this method include comparatively safe conditions and functional recovery, there were also some problems. It was inappropriate for cases of radiation osteomyelitis of the mandible; those where anti-inflammatory therapy was ineffective; and those where greater resection of the soft tissue was required. Further study is needed to clarify the criteria for selecting this procedure.

Key words: Free vascularized fibular transplant — Mandibular reconstruction — Oral tumor — Mandibular bone — Mandibular defect
Introduction

The primary goals of reconstruction after resection of the mandible are to restore a range of functions that may have been impaired, including articulation, chewing, and swallowing, and improve esthetics. This is usually achieved by means of a metal plate and bone graft. Currently, a free vascularized fibular graft, such as an iliac block graft, is the most commonly used biomaterial for this purpose. Since the ratio between the cortex and cancellous bone in iliac horn bone is similar to that of the mandible, such grafts are considered to be the most suitable for mandibular reconstruction. From the viewpoint of bone absorption and increased susceptibility to infection, free vascularized fibular grafts, comprising living bone, have shown a lower infection rate and high rate of success, reasons for which they are now in common use in mandibular reconstruction. Their use in transplantation was first reported by Taylor et al. in 1975; and their first use in the craniocervical region was later reported by Hidalgo. They rely on the fibular artery/vein as the main feeding vessel. It is possible to harvest grafts of greater than 20 cm in length, making them useful in the reconstruction of defects across a wide range of mandibular bone conditions. Their use also allows osteotomies to be performed at multiple locations and harvesting with the patient in the supine position. Another advantage of adopting this approach to mandibular reconstruction is that there are fewer postoperative complications related to the site of harvest, which is why it has been adopted at the Department of Oral and Maxillofacial Surgery at Tokyo Dental College Chiba Hospital in cases where an iliac block graft was deemed too difficult.

This report describes mandibular reconstruction employing vascularized fibular grafts at our department.

Patients and Methods

1. Patients

The study population comprised 8 out of 137 patients (5.8%) undergoing mandibular reconstruction by transplantation of a free vascularized fibular graft following mandibular resection. All had undergone segmental resection of the mandible at the Department of Oral and Maxillofacial Surgery at the Tokyo Dental College Chiba Hospital over a period of 14 years and 1 month, between January 2003 and January 2017 (Table 1). The following factors were taken into consideration in these cases: age, sex, primary disease, period of reconstruction, mandibular defect classification, mandible resection range, height of reconstructed mandibular bone, number of locations of mandible osteotomy, and complications. Mandibular defect classification was carried out based on the CAT system of Hashikawa et al. (Condylar Head, Mandibular Angle, Mental Tubercle). The criteria for fibular transplantation were as follows: infection or necrosis of bone transplanted at the time of primary reconstruction; multiple failure of the metal plate for reconstruction; an extensive defect range in the mandible, making reconstruction by transplantation of an iliac bone block graft potentially difficult; and radiation osteomyelitis. As a fibular graft is living bone with blood flow, unlike an iliac bone graft, it has strong resistance to infection, making it the most suitable type of graft for a wide range of defects. For these reasons, fibular bone grafts are selected at our department as the primary treatment in cases of mandibular reconstruction where a wide range of defects would make reconstruction difficult due to limitations on the amount of bone that could be harvested by other means. Patients with systemic illness in whom it would have been difficult to perform surgery under general anesthesia, and those suspected of having deep vein thrombosis were excluded from the study. Written informed consent was obtained from all patients for inclusion in this study.
2. CAT classification (Fig. 1)

The CAT classification is determined according to 3 factors, making a total of 6 bilaterally: the Condylar Head, Mandibular Angle, and Mental Tubercle, as standard points; followed by designation of each as a C, A, or T point. The mandibular defect is classified by a combination of these points. If a defect includes a standard point, it is classified as C, A, or T; if it includes multiple standard points, it is classified as CA, AT, or CAT. If a case involves resection at a standard point, it is not included in the classification. If a defect is restricted to the mandibular ramus with no standard point, it is classified as Neck; if it is restricted to the body of the mandible, it is classified as Body.

The CAT classification may be summarized as follows: 1) there are 14 classification patterns; 2) only bone defects are included (soft tissue defects are not addressed); and 3) classification is simple to perform.

3. Method

The range of mandibular resection was classified into 4 groups as follows: less than 8 cm in length; greater than 8 cm and less than 12 cm; greater than 12 cm and less than 16 cm; and greater than 16 cm. The number of osteotomy sites during mandibular formation was classified into the 3 groups, which were designated 0, 1, and 2.

Preoperative model surgery was performed using a plaster molded, 3-dimensional patient model prepared based on CT data of the mandibular bone. A cutting guide was then prepared using a Schuchart splint based on the 3-dimensional actual model.

The presence or absence of postoperative complications, primary disease, mandible resection range, and number of mandible osteotomy sites were considered. A skin flap was also harvested during engraftment of the bone flap and evaluated as a monitoring parameter.

## Table 1 Patients information

| Case | Age | Gender | Primary disease | CAT classification | Mandible resection range | Barrel | Piece | Complication |
|------|-----|--------|----------------|--------------------|--------------------------|--------|-------|--------------|
| 1    | 50  | M      | Mandibular gingival carcinoma post operation | TT | 7 cm | single | two | no |
| 2    | 62  | M      | Ameloblastoma post operation | AT | 9 cm | single | two | no |
| 3    | 52  | M      | Mandibular gingival carcinoma post operation | ATTA | 16 cm | single | three | no |
| 4    | 38  | M      | Aneurysmal bone cyst/ Fibrous dysplasia | Body | 8 cm | double | one | no |
| 5    | 64  | M      | Radiation osteomyelitis | Body | 7 cm | single | one | necrosis |
| 6    | 47  | F      | Radiation osteomyelitis | CATT | 16 cm | single | four | necrosis |
| 7    | 74  | F      | Mandibular gingival carcinoma post operation | AT | 12 cm | single | two | no |
| 8    | 45  | M      | Ameloblastoma post operation | Body | 5 cm | single | one | no |
The artery used for the anastomotic vessel was set as the peroneal artery, superior thyroid artery, or facial artery; the artery common facial vein; or middle thyroid vein. The number of sutures was set as 1 for the artery and 2 for the vein, for a total of 3 sutures. The number of mini-plates used for osteosynthesis was set at 2 plates in cases where the height of the fibula was 10 mm or greater. In cases where this was less than 10 mm, the bone was set with 1 mini-plate or a screw.

Results

1. Sex, age, operation time, and bleeding

Six of the patients were men, and 2 were women. Age ranged from 38 to 74 years, with an average of 54 years.

Operation time was 5 hr 15 min–13 hr 8 min (mean, 7 hr 54 min). Blood loss was 263–3,710 ml (mean, 907.5 ml).
2. Period of reconstruction and primary disease (Table 2)

There were 3 cases of primary reconstruction (37.5%), and 5 of secondary reconstruction (62.5%). Primary disease comprised malignant tumor in 3 cases (37.5%), benign tumor in 3 cases (37.5%), and radiation osteomyelitis of the mandible in 2 cases (25%).

3. Mandibular defect classification and mandible resection range (Table 3); height of reconstructed mandibular bone

According to the CAT classification, Body was the most commonly observed defect (37.5%), followed by 2 cases of AT (25%), and 1 case each of TT, ATTA, and CATT. The resection range of the mandible was 5–16 cm (mean, 10 cm). Less than 8 cm was the most frequent in 3 cases (37.5%); followed by greater than 8 cm and less than 12 cm in 2 cases (25%); greater than 12 cm and less than 16 cm in 1 case; and greater than 16 cm in 2 cases (25%). The mandibular bone was folded into a double barrel in order to obtain sufficient height for the reconstructed mandibular bone in 1 case; it was left unfolded, as a single barrel, in 7 cases.
4. Number of mandibular osteotomy sites and resection range

(Table 4)

In the 3 cases in which the mandibular resection range was less than 8 cm, and in 2 cases in which the defect range was in the molar region, the defect was straight and did not require mandibular osteotomy. In 1 case in which the defect included canines bilaterally, however, osteotomy was performed in one location for esthetic reasons. In the 2 cases in which the resection range was greater than 8 cm and less than 12 cm, 1 case did not require an osteotomy, and the double barrel technique was used to reconstruct the alveolar area. In the other case, the mandibular angle area was included, so osteotomy was performed at one site. In all 3 cases with a resection range of 12 cm or greater, osteotomy was performed. Among these, 2 required an osteotomy at more than 2 sites. This demonstrated that the need for an osteotomy at more than 2 sites for esthetic reasons is likely to grow with an increase in the range of mandibular resection.

5. Postoperative complications (Tables 5, 6)

Postoperative complications were observed in 2 cases, both of which comprised bone flap necrosis on the transplant bone. Regarding the correlation between frequency of occurrence of bone flap necrosis and number of mandibular osteotomy sites, no osteotomy was performed in 1 case, while 3 were performed in another in which bone flap necrosis was present (Table 5).

Regarding the correlation between frequency of occurrence of bone flap necrosis and the range of mandibular resection, a resection range of less than 8 cm was adopted in 1 case, while a range of greater than 16 cm was adopted in the other, in which bone flap necrosis was present (Table 6).

Regarding the correlation between frequency of occurrence of bone flap necrosis and primary disease, both patients with observed bone flap necrosis also had radiation osteomyelitis of the mandible.

No complications, such as difficulty in walking, were observed in any cases of harvested fibular bone.

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Table 4  Number of locations of mandibular osteotomy and the resection range

| Number of osteotomy | Mandible resection range (cm) | Total |
|---------------------|-------------------------------|-------|
|                     | <8  | 8≤<12 | 12≤<16 | 16≤ |       |
| 0 places            | 2   | 1     | 0      | 0   | 3   |
| one place           | 1   | 1     | 1      | 0   | 3   |
| more than two places| 0   | 0     | 0      | 2   | 2   |
| Total               | 3   | 2     | 1      | 2   | 8   |

Table 5  Postoperative complication and number of osteotomy

| Number of osteotomy | Frequency of complication (bone flap necrosis) (%) |
|---------------------|---------------------------------------------------|
| 0 places            | 1 case/3 cases (33.3%)                            |
| one place           | 0 case/3 cases (0%)                               |
| more than two places| 1 case/2 cases (50%)                              |
| Total               | 2 cases/8 cases (25%)                             |

Table 6  Postoperative complication and mandibular resection range

| Mandible resection range (cm) | Frequency of complication (bone flap necrosis) (%) |
|-------------------------------|---------------------------------------------------|
| <8                            | 1 case/3 cases (33.3%)                            |
| 8≤<12                         | 0 case/2 cases (0%)                               |
| 12≤<16                        | 0 case/1 case (0%)                                |
| 16≤                           | 1 case/2 cases (50%)                              |
| Total                         | 2 cases/8 cases (25%)                             |
6. Cases (Figs. 2–9)

Case 1 comprised a 50-year-old man with postoperative mandibular gingival cancer. His CAT classification was TT; the mandibular defect range was 7 cm; the number of mandible osteotomy sites was 2 at 1 site; and the height of the mandible reconstruction was single barrel. Mandibular bone engraftment was good (Fig. 2). Recovery of function by means of an artificial tooth was attempted during reconstruction of postoperative occlusion. A significant improvement was observed in postoperative occlusion compared to preoperative conditions, and the patient was satisfied. The follow-up period was 14 years 1 month.

Case 2 comprised a 62-year-old man with postoperative ameloblastoma. His CAT classification was AT; the mandibular defect range was 9 cm; the number of mandible osteotomy sites was 2 at 1 site; and the height of the mandible reconstruction was single barrel. Mandibular bone engraftment was good (Fig. 3). Recovery of function by means of an artificial tooth was attempted during reconstruction of postoperative occlusion. Stable occlusion was subsequently obtained compared to preoperative conditions, and the patient was also satisfied with the cosmetic results. The follow-up period was 7 years 8 months.

Case 3 comprised a 52-year-old man with postoperative mandibular gingival cancer. His CAT classification was ATTA; the mandibular defect range was 16 cm; the number of mandible osteotomy sites was 3 at 2 sites; and the height of the mandible reconstruction was single barrel. Mandibular bone engraftment was good (Fig. 4). Recovery of function by means of an artificial tooth was attempted during reconstruction of postoperative occlusion. A significant improvement in stability of postoperative occlusion and increased occlusion strength were obtained compared to preoperative conditions. The patient was also satisfied with the cosmetic results. The follow-up period was 7 years 6
months.

Case 4 comprised a 38-year-old man with the complications of aneurysmal bone cyst and fibrous dysplasia. His CAT classification was Body; the mandibular defect range was 8 cm; the number of mandible osteotomy sites was 1 at 0 sites; and the height of mandible reconstruction was double barrel. Mandibular bone engraftment was good (Fig. 5). This patient was younger than the others, had a greater number of remaining teeth, and a stronger biting force. He desired reconstruction of occlusion with an implant, so a double barrel was selected to reconstruct the residual ridge with sufficient height to allow this. The patient requested postoperative prosthetic
treatment with artificial teeth. Recovery of occlusion was subsequently obtained by means of artificial teeth. Regarding postoperative occlusion, even though the patient lost 4 molars, stable occlusion was obtained compared to preoperative conditions. The follow-up period was 7 years 4 months.

Case 5 comprised a 64-year-old man with radiation osteomyelitis and mandibular gingival cancer. His CAT classification was Body; the mandibular defect range was 7 cm; the number of mandible osteotomy sites was 1 at 0 sites; and the height of mandible reconstruction was single barrel. Mandibular bone showed total necrosis due to infection (Fig. 6). No prosthetic measures were carried out during postoperative occlusion reconstruction due to systemic deterioration. Dislocation of the temporomandibular joint on the right side was observed on a postoperative X-ray (Fig. 6), the mandibular bone showed total necrosis due to infection in the early postoperative period, and his general condition had worsened. Consequently, no treatment or occlusion reconstruction was performed for the dislocation. Hence, preoperative and postoperative occlusion was not evaluated. The follow-up period was 5 years 7 months.

Case 6 comprised a 47-year-old woman with radiation osteomyelitis and mandibular gingival cancer. Her CAT classification was CATT; the mandibular defect range was 16 cm; the number of mandible osteotomy sites was 3 at 2 sites; and the height of mandible reconstruction was single barrel. Mandibular bone showed total necrosis due to infection (Fig. 7). Recovery of occlusion function was not achieved during reconstruction of postoperative occlusion due to total necrosis of the fibula. Hence, preoperative and postoperative occlusion were not evaluated. The follow-up period was 3 years 11 months.

Case 7 comprised a 74-year-old woman with complications of aneurysmal bone cyst and fibrous dysplasia.
postoperative mandibular gingival cancer. Her CAT classification was AT; the mandibular defect range was 12 cm; the number of mandible osteotomy sites was 2 at 1 site; and the height of the mandible reconstruction was single barrel. Mandibular bone engraftment was good (Fig. 8). Recovery of function by means of an artificial tooth was attempted during reconstruction of postoperative occlusion. Postoperative occlusion has been stable compared to preoperative conditions. The follow-up period was 1 year 1 month.

Case 8 comprised a 45-year-old man with postoperative ameloblastoma. His CAT classification was Body; the mandibular defect range was 5 cm; the number of mandible osteotomy sites was 1 at 0 sites; and the height of mandible reconstruction was single barrel. Mandibular bone engraftment was good (Fig. 9). Recovery of function by means of an artificial tooth was attempted during reconstruction of postoperative occlusion. Postoperative occlusion has been significantly stable compared to preoperative conditions, and increased occlusion strength was obtained. The follow-up period was 10 months.

Discussion

A specific approach is adopted at Tokyo Dental College in the basic reconstruction of the defective area following resection of the mandible. This comprises either a block transplant using just a metal plate, or a metal plate and free iliac bone. In many cases of reconstruction with only a metal plate in
patients with a lot of remaining teeth and a strong bite force, however, re-surgery has been required due to screw loosening at the point of fixation or breakage of the plate. An earlier study also reported that reconstruction with only a metal plate was useful as a temporary solution, but that it had long-term problems. On the other hand, block transplant using free iliac bone also has disadvantages, such as limitations on the amount of bone which can be harvested, and bone absorption after transplant. Furthermore, application is also limited due to the condition of the transplant bed, which is sometimes compromised, such as after exposure to radiation. Here at our department, application of a block transplant in conjunction with free iliac bone is only indicated in cases with no history of radiation exposure, and in those with a history of hemisection. This is because reconstruction requiring extensive bilateral segmental resection is considered difficult.

Some studies have suggested that this problem can be overcome by reconstructing the mandible by means of a vascularized osteocortical flap in conjunction with microvascular surgery. The fibula is especially suitable for mandibular reconstruction in terms of bone length, strength, multiplicity of cortical bones, adaptability to bone formation, and disturbance of the site of harvest. One study recommended the fibula as the first choice in mandibular reconstruction.

Earlier studies have noted a number of other advantages with a fibular graft in this respect. These include a high engraftment
ratio; no observed bone absorption; applicability in most cases as fibular bone can be collected in lengths of up to 20 cm; osteotomy of bone graft, allowing 3-dimensional configuration of mandibular bone, if the alveolar area can be reconstructed by folding into two (double barrel method); and suitability for insertion of implant. In the present study, postoperative recovery of occlusal function was achieved by means of artificial teeth in 6 patients, and with no prosthetic treatment in 2. No implants were used to restore occlusion, here. This does not mean that implants will be ruled out in future patients, however, and the decision will have to be made based on comprehensive consideration of both fibular height and soft tissue conditions. At such time, the width of the attached gingiva of soft tissue should also be considered, even if planting is possible using a long implant.

Reproducing the position of the remaining mandibular bone, which is segmentally resected, and of which the continuity is cut, and forming the fibula by adjusting the form of the defect area, are important. Jaw position has been reproduced using intermaxillary fixation and plates for many years at Tokyo Dental College. It was found that greater accuracy could be achieved in reconstruction and surgical time reduced if the bone to be transplanted was adjusted in accordance with plaster molded 3-dimensional models in order to confirm compatibility first. A comparison of mean operation time and blood loss between 16 cases of reconstruction by iliac bone block transplant performed over the last 6 years and the present 8 cases revealed that the mean operation time by the former method was 5.3 hr, and mean blood loss 471.3 ml, while that in latter was 7.9 hr and 907.5 ml, respectively. Thus, iliac block transplant requires a shorter operation time and a lower level of blood loss. This disparity is likely explained by the fact that a fibular transplant requires a microsurgical angiostomy, which constitutes an extra procedure requiring additional time and an increase in blood loss.

The correlations among the number of fibular osteotomy sites, mandible resection range, primary disease, and fibular necrosis were also investigated. No correlation was observed between fibular necrosis and the number of fibular osteotomy sites or range of mandibular resection. A correlation with primary diseases was indicated, however.

Both cases of observed fibular necrosis had radiation osteomyelitis of the mandible as the primary disease. One major advantage of the fibula is that the tip can be adopted even in a radiation-exposed transplant bed, since blood flow can be directed straight to the transplanted bone. In the 2 cases of radiation osteomyelitis of the mandible here, however, vascular breakdown after wound infection was observed, resulting in necrosis of the fibular bone. In both cases, this was due to clot formation in the arterial anastomosis in the high-dose radiation exposure field, which spread to the cervical region. Even when there is short vascularization of the bone flap, anastomosis requires great care within a field of high-dose radiation.

One study reported that cases of total necrosis of fibular bone in the arterial anastomosis region of the radiation exposure field in radiation jaw osteonecrosis had a lower take ratio than other cases, and concluded that angiostomy in the radiation exposure field which spreads to the cervical region requires careful attention. When a fibular transplant is performed in a patient with radiation osteomyelitis of the mandible, a number of steps will have to be taken further along. These comprise: 1) performing the surgery after improvement of infection of the mouth and neck; 2) selecting appropriate postoperative antibiotics that are effective against osteomyelitis and performing drainage more strictly; and 3) displaying caution when selecting a blood vessel for anastomosis outside the exposure field. In conclusion, the results of the present study suggest the following cases should indicate selection of a vascularized fibular graft: 1) wide-range defects difficult to fill with an iliac block graft; 2) blockage or necrosis of the iliac block; 3) multiple fractures of the metal plate for reconstruction; and 4) radiation osteomyelitis of
the mandible, where the radiation has not penetrated the neck, and no continuous production of pus is observed. Further studies involving larger samples of patients undergoing fibular bone transplantation are needed to comparatively investigate its merits in relation to iliac bone block grafts in more detail.

Acknowledgements and Conflict of Interest

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