Introduction

Free fibula flap is the most useful flap for segmental mandibular defects (1-4). Free fibula reconstruction requires long operation time and special microsurgical technique. Microsurgical technique could be mastered through preclinical experiments, however, time-consuming mandibulectomy and fibular bending requires more efficient way to expedite operation. One of the easiest ways to reduce intraoperative time is using simulation surgery with virtual 3-dimensional (3D) model before surgery (4-7). Mock surgery using 3D rapid prototype (RP) model gives a lot of information for mandibular reconstruction. The purpose of this study was to report mandibular reconstruction with free fibular flap using simulation surgery. A total of 30 consecutive patients were included for functional and esthetic evaluation. Among 30 patients, two flaps showed necrosis after radiotherapy. The other flaps were all survived and showed successful reconstruction in both function and esthetics.

Key Words: 3D RP · Simulation surgery · Fibula free flap · Mandibular reconstruction.

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respectively. The postoperative results of mandibular reconstruction using simulation surgery were reviewed.

**Materials and Methods**

A total of 30 consecutive patients who underwent free fibular reconstruction between May 2006 and September 2015 were included in this study. Male to female patients was 14:16 and average age was 60.6±12 years old (27-77). Secondary reconstruction was performed in four patients and the others were reconstructed simultaneously with primary resection of the mandibular lesions. Thirteen patients were diagnosed as squamous cell carcinoma in the mandibular gingiva invaded into mandible and there were eight osteoradionecrosis, five osteomyelitis, two ameloblastoma and two mandibular osteosarcoma.

For simulation surgery before mandibular reconstruction, a 3D RP mandibular model was made with facial 3D CT scan data. When patient needed resection of temporomandibular joint, half-skull RP model was fabricated to verify the relationship between mandibular condyle and mandibular fossa.

Before mandibulectomy, arch bar were applied in both maxilla and mandible for occlusion except one patient with full edentulism. Thin (2.4 mm) titanium reconstruction plates (SGM plate, Seoul, Korea or Leibinger, San Diego, USA) were applied before mandibular resection. Right after mandibular resection, reconstruction plates were repositioned and intermaxillary fixation (IMF) was performed. Fibula flap was selected according to the defect. Intraoral mucosa defect with mesial side vessels direction was the indication for ipsilateral side harvest. Free fibula flap was fixed to the mandibular defect using

**Table 1. Demographic data of the patients and flap survival**

| No | Op Date | Sex | Age | Disease | Recon type | Flap Survival | Condyle |
|----|---------|-----|-----|---------|------------|--------------|---------|
| 1  | 2006-05-24 | F | 69 | BRONJ | 1 | Yes | No |
| 2  | 2006-10-25 | M | 69 | Osteomyelitis | 1 | Yes | Yes |
| 3  | 2006-12-07 | M | 54 | Ameloblastoma | 1 | Yes | No |
| 4  | 2007-08-29 | F | 51 | SCC | 1 | Yes | No |
| 5  | 2007-12-26 | M | 51 | SCC | 2 | Yes | No |
| 6  | 2008-03-26 | M | 51 | ORN | 1 | Yes | No |
| 7  | 2008-10-01 | F | 77 | SCC | 1 | Yes | No |
| 8  | 2009-04-22 | M | 54 | ORN | 1 | Yes | No |
| 9  | 2009-07-29 | M | 70 | ORN | 1 | Yes | No |
| 10 | 2009-12-02 | M | 62 | SCC | 1 | Yes | No |
| 11 | 2010-06-23 | F | 53 | Ameloblastoma | 2 | Yes | No |
| 12 | 2010-10-13 | M | 49 | SCC | 1 | Yes | No |
| 13 | 2010-12-29 | M | 63 | SCC | 1 | Yes | No |
| 14 | 2011-01-12 | F | 77 | SCC | 1 | Yes | No |
| 15 | 2012-11-05 | F | 69 | SCC | 1 | Yes | No |
| 16 | 2013-07-29 | M | 67 | SCC | 1 | Yes | No |
| 17 | 2013-10-21 | F | 68 | BRONJ | 1 | Yes | No |
| 18 | 2013-11-11 | F | 77 | SCC | 1 | No | No |
| 19 | 2014-02-24 | F | 62 | BRONJ | 1 | Yes | No |
| 20 | 2014-08-22 | F | 69 | ORN | 1 | Yes | No |
| 21 | 2014-09-24 | M | 70 | BRONJ | 1 | Yes | No |
| 22 | 2014-10-20 | M | 68 | SCC | 1 | Yes | No |
| 23 | 2014-10-29 | F | 67 | ORN | 1 | Yes | No |
| 24 | 2014-11-03 | F | 49 | ORN | 1 | Yes | No |
| 25 | 2014-11-24 | M | 70 | ORN | 2 | Yes | No |
| 26 | 2015-02-02 | F | 47 | SCC | 2 | Yes | Yes |
| 27 | 2015-03-30 | F | 68 | SCC | 1 | No | No |
| 28 | 2015-06-08 | F | 27 | Osteosarcoma | 1 | Yes | No |
| 29 | 2015-07-20 | M | 51 | ORN | 1 | Yes | No |
| 30 | 2015-09-30 | F | 39 | Osteosarcoma | 1 | Yes | No |

Op: operation, Recon: reconstruction, F: female, M: male, SCC: squamous cell carcinoma, ORN: osteoradionecrosis, BRONJ: bisphosphonate related osteonecrosis of the jaw, Condyle: including condyle during mandibulectomy
bicortical screws. Postoperative IMF was performed about 1 week and mouth opening exercise was performed using elastic rubber ring guidance. Postoperative flap survivals, postoperative occlusion, esthetic results, food taking were evaluated.

**Results**

All fibular flaps were survived after operation. Patients' demographic data and cause of bone defects is listed in Table 1. Two patients who had undergone radiotherapy for 8 weeks showed progressive necrosis of the flaps. These two flaps were removed under local and general anesthesia. Seven patients passed away during follow-up periods and among them, four patients died of recurrent squamous cell carcinoma. The others died of other causes such as cerebral infarction and pneumonia. Simulation surgery and prebending R-plate could reduce surgical operation time dramatically.

Occlusal stability after segmental mandibulectomy was obtained in 29 patients. One full edentulism patient reported liquid diet after operation. This edentulous patient required dental implant and overdenture for restoration, however, prosthodontic treatment is pending due to economic status. Dental implants were placed in the reconstructed mandible in four patients without any failure. All patients were satisfied with the esthetic results. No patient complained about donor site morbidity postoperation 3 months. Patients who underwent dental implant therapy reported improved solid food intake.

**Discussion**

Fibula free flap is one of the most popular free flaps for the mandibular reconstruction (7, 8). The advantages of the fibula free flap are long bone, consistent vessels, concomitant skin harvest and enough bone volume for dental implant installation (1, 4, 9). However, straight nature of the fibula bone needs multiple segmentations for fitting mandibular contour. Intraoperative segmentation and fixation is time-consuming procedure. Prolonged operation time increases ischemic hypoxia of free flap which is related with flap failure. To decrease ischemic time, osteotomy without disconnecting peroneal vessels, surgical stent application and simulation surgery were clinically tried. Osteotomy without disconnecting peroneal vessels is good to maintain blood supply to the fibular flap, however, exact prefabrication is necessary for adapting in the mandibular defect. If the prebent fibula flap does not fit, miniplates for fixation of the fibular osteotomy should be removed and reapplied (10, 11). This procedure protracted anastomosis of the vessels and increase ischemic injury. Delayed anastomosis and reperfusion could jeopardize free flap (12-14).

Titanium reconstruction plate (R-plate) is rigid and easy to apply in the segmental mandibular bone defect (15, 16). There are controversies about miniplates application vs R-plate insertion during fibular free flap reconstruction. Each methods has advantages and disadvantages such as easy to apply (R-plate) and removal (miniplates), rigidity for early masticatory function (R-plate), no risks for skin exposure (miniplates) and easy to fix the fibular flap (R-plate).

Recently, virtual simulation surgery before mandibular reconstruction was tried in many institutions (5, 17-19). The advent of preoperative virtual surgical planning with 3D RP model and simulation surgery before operation has resulted in more efficient and less traumatic and fast surgery (15). When ischemic time has been reduced below one hour, success rate of free flap is increased dramatically. Experienced surgeons know the procedure completely and two-team approach can reduce operation time. However, a novice needs special program to master microsurgical reconstruction. Preclinical can use virtual program and could make surgical guidance for fibular osteotome.

**Conclusion**

Simulation surgery before mandibular reconstruction is the most efficient way to reduce operation time and postoperative complication such as malocclusion, facial asymmetry and flap necrosis. In this study, 28 patients were satisfied with the mandibular reconstruction and showed good occlusion. Postoperative physical therapy for occlusal guidance is mandatory for successful results.

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