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Improving the accuracy of mandibular reconstruction with vascularized iliac crest flap: Role of computer-assisted techniques

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ABSTRACT

While vascularized iliac crest flap is widely used for mandibular reconstruction, it is often challenging to predict the clinical outcome in a conventional operation based solely on the surgeon's experience. Herein, we aimed to improve this procedure by using computer-assisted techniques. We retrospectively reviewed records of 45 patients with mandibular tumor who underwent mandibulectomy and reconstruction with vascularized iliac crest flap from January 2008 to June 2015. Computer-assisted techniques including virtual plan, stereomodel, pre-bending individual reconstruction plate, and surgical navigation were used in 15 patients. The other 30 patients underwent conventional surgery based on the surgeon's experience. Condyle position and reconstructed mandible contour were evaluated based on post-operative computed tomography. Complications were also evaluated during the follow-up. Flap success rate of the patients was 95.6% (43/45). Those in the computer-assisted group presented with better outcomes of the mandibular contour ($p = 0.001$) and condyle position ($p = 0.026$). Further, they also experienced beneficial dental restoration ($p = 0.011$) and postoperative appearance ($p = 0.028$). The difference between postoperative effect and virtual plan was within the acceptable error margin. There is no significant difference in the incidence of post-operative complications. Thus, computer-assisted techniques can improve the clinical outcomes of mandibular reconstruction with vascularized iliac crest flap.

1. Introduction

Oral and maxillofacial surgeons are often faced with the challenging task of achieving functional and cosmetic reconstruction of mandibular defects after tumor ablation. Nowadays, vascularized bone grafts have become the first choice for mandibular reconstruction because of the associated high survival rates and satisfactory long-term outcomes. Free fibula flap and free iliac crest flap are most widely used (Hidalgo, 1989; Disa and Cordeiro, 2000; Munoz Guerra et al., 2001; Lyons et al., 2005). The iliac crest flap is more favorable than the free fibula flap for some surgeons because of the large amount of bone volume, rich cancellous blood supply, and compact cortex, which make it an ideal choice for plate fixation and implant placement for dental restoration (Munoz Guerra et al., 2001; Lyons et al., 2005).

The free iliac crest flap is also known as deep circumflex iliac artery (DCIA) flap, which was first introduced for mandibular reconstruction by Taylor in 1979 (Taylor et al., 1979). Traditionally, surgeons have had to use their experience and skill to determine the method of performing osteotomy and graft harvesting and shaping. The functional and cosmetic outcomes are sometimes dissatisfactory owing to the inaccuracy of the reconstruction procedure.

With the rapid development of radiological and digital technologies, computer-assisted techniques have been widely used in oral and maxillofacial surgeries. Techniques such as virtual surgical plan, rapid prototyping, and surgical navigation could offer more effective and predictable outcomes (Cinquin et al., 1995; Schubert et al., 2002; Fernandes and DiPasquale, 2007; Yu et al., 2010). Therefore, the aim of our study was to evaluate the benefit of computer-assisted mandibular reconstruction using free iliac crest flap with respect to the functional and cosmetic results.

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2. Material and methods

2.1. Patient demographics

Between January 2008 and June 2015, 45 patients (21 men, 24 women) with mandibular tumors underwent mandibulectomy and simultaneous reconstruction with free iliac crest flaps at our institute. The inclusion criteria were as follows: (1) mandibular pathology required for mandibulectomy, (2) simultaneous mandibular reconstruction with free iliac crest flap, and (3) the lesion should have only invaded the mandibular body and part of the ramus of the mandible so that the condyle could be preserved. Patients with a history of tumor ablation and jaw reconstruction were excluded.

The patients were divided into two groups: those who underwent computer-assisted surgery (n = 15; mean age, 36.7 ± 17.5 years) and those who underwent reconstruction based on the surgeon's experience (n = 30; mean age, 36.4 ± 13.2 years). All patients in the computer-assisted surgery group had benign tumors, of which 10 were ameloblastomas and the other 5 were ossifying fibromas. In the other group, 26 patients had benign tumors and 4 had malignant tumors. Patients in both groups were followed up for at least 6 months. No local recurrence occurred, and all patients lived without disease until the last follow up (December 2015) (Table 1).

2.2. Virtual planning

Preoperative virtual planning was performed in the computer-assisted surgery group. Computed tomography (CT) of the head, neck, and iliac bone were performed (field of view, 20 cm; pitch, 1.0; slice, 0.75 mm; 120Y280 mA). The CT data of head and neck in the Digital Imaging and Communications in Medicine (DICOM) format were imported to the ProPlan CMF software (ProPlan CMF, Materialise NV, Leuven, Belgium). First, the mandible and maxilla were segmented. Then, we performed virtual mandibulectomy according to clinical and 3D radiological examination and evaluation (Fig. 1). Meanwhile, the CT data of the iliac bone was also imported to the ProPlan CMF software and the donor site was segmented, following which we superimposed the 3D iliac image on the mandibular defect in its desired orientation according to the ideal mandibular contour (Fig. 2). If the contour of the mandible was destroyed by the tumor, mirroring image based on the unaffected side was used to form the ideal mandibular contour. After the computer-assisted virtual plan was generated, an ideal reconstructed stereomodel was manufactured using 3D printing technology. A reconstruction plate was prebent and fixed on the reconstructed mandibular model using titanium screws (Fig. 3). In addition, the designed part of the iliac crest was printed as a resin model, in order to make an iliac crest-cutting template with thermoplastic resin to guide the harvest and molding of the iliac flap (Fig. 4).

Next, the mandibular model with the reconstruction plate was subjected to CT scanning (field of view, 20 cm; pitch, 1.0; slice, 0.75 mm; 120Y280 mA), and the CT data were imported to the ProPlan CMF software in DICOM format. The model was segmented and registered with the reconstructed mandible that we had previously virtually designed. The positions of the titanium screws were marked for the accuracy of locating the plate during surgery.

Finally, all the planned data was transferred into iPlan CMF 3.0 software (Brainlab, Feldkirchen, Germany) and an individual navigation protocol was generated for presentation during the surgery.

2.3. Surgical procedure

In the computer-assisted surgery group, tumor resection and mandibulectomy were performed according to the virtual plan, completely guided by a computerized navigation system (BrainLAB, AG, Feldkirchen, Germany). The osteotomy lines were confirmed and marked by the navigation system (Fig. 5). After the tumor resection and mandibulectomy, the occlusion was fixed by the arch bar and the osteotomy site would be confirmed again by the surgical navigation. Then, the reconstruction plate was fixed on the remaining mandibular segment guided by the navigation system, according to the six marked points indicating the position of the titanium screws (Fig. 6). The donor site was ipsilateral to the maxillectomy site. The iliac crest flap was harvested, as described by Taylor et al. (1979), simultaneously with the mandibulectomy. The flap was harvested and molded by the resin model and cutting template as mentioned earlier (Fig. 4). The flap was transferred to the recipient site, and the pedicle was placed within a tunnel in the submandibular region to promote anastomosis. The three-dimensional position was confirmed to match the position in the virtual plan by using the navigation system (Fig. 6).

In the traditional surgery group, tumor resection and mandibular reconstruction were based on the surgeon's experience without any virtual planning or model design. The flap was fixed to the mandibular segment with reconstruction plate or mini plate (12 reconstruction plates and 18 mini plates) based on the surgeon's decision.

2.4. Outcome evaluation

Postoperative CT scan was performed for all patients. Both the preoperative and postoperative CT data were imported into

Table 1
Patient characteristics.

Groups		Computer-assisted group (n = 15)	Traditional group (n = 30)
Age (years)		36.7 ± 17.5	36.4 ± 13.2
Gender	M/F	6/9	15/15
Primary disease	Ameloblastoma	10	15
	Ossifying fibroma	5	7
	Odontogenic myxoma	0	3
	Odontogenic ghost cell tumor	0	1
	Gingival carcinoma	0	3
	Osteosarcoma	0	1
Type of plate	Reconstructing plate	15	12
	Mini plate	0	18
Complications	Flap failure	1	1
	Plate exposure	0	0
	Plate breakage	0	0
	Infection	1	3
	Malocclusion	0	2