CLINICAL ORAL IMPLANTS RESEARCH

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Comparative analysis of dental implant treatment outcomes following mandibular reconstruction with double-barrel fibula bone grafting or vertical distraction osteogenesis fibula: a retrospective study

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Abstract

Purpose: The purpose of this study was twofold: (i) to compare vertical bone height (VBH) after tumor resection through grafting with either a double-barrel fibula (DBF) technique or vertical distraction osteogenesis of the fibula (VDOF); (ii) to compare the performance of loaded dental implants following either DBF or VDOF with special focus on implant survival, implant success, and bone resorption.

Materials and methods: This retrospective clinical study involved 19 patients who underwent implant placement following DBF (group A, $n = 9$) or VDOF (group B, $n = 10$) for mandibular reconstruction from March 2006 to May 2008. Clinical and radiographic assessments, including VBH, modified Plaque Index (mPI), modified Sulcus Bleeding Index (mSBI), and marginal bone level (MBL), were taken for both groups after delivery of the final prostheses and annually thereafter.

Results: Nine patients underwent DBF with 24 implants placed and 10 patients underwent VDOF with 27 implants placed for mandibular reconstruction after tumor resection. Overall, all DBF and VDOF procedures were successful for group A and group B. VBH for group A and group B were 20 and 17 mm. There was no statistically significant difference of mSBI scores between group A and group B in the 3-year follow-up ($P = 0.40$). In four cases with eight implants of group A and two cases with three implants of group B, granulomatous soft tissue grew. There was no statistically significant differences of MBL between group A and group B in the 3-year follow-up ($p = 0.736$). The cumulative survival and success rates of implants for group A were 100% and 87.5%, and for group B were 100% and 85.2% in 3-year follow-up, respectively.

Conclusions: On the basis of the study of 19 patients who received a total of 51 implants, reconstruction of the mandible with DBF flap or VDOF flap, combined with dental implant therapy, was considered a predictable option. Compared with implants placed in VDOF bone, implants placed in DBF bone had a relative higher incidence of associated gingival inflammation. The DBF bone seems more resistant to peri-implant resorption processes than VDOF bone during functional loading.

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Over the past 20 years, the fibular free flap technique has become a routine procedure for the functional reconstruction of the mandible to correct mandibular continuity defects that are caused by tumors resection (Sieg et al. 2002). The most common problem encountered with this method is the insufficient bone height of the fibula, which results in a gap between the bone margin and the occlusal plane, in particular, in patients treated by partial resection of the mandible with residual dentition on the healthy side (Frodel et al. 1993; Moscoso et al. 1994; Matsuura et al. 1999; Anne-Gaëlle et al. 2011).

The height discrepancy between native bone and graft fibula makes it less likely for

prostheses to achieve a desirable implant-to-crown ratio and increases the difficulty in maintaining adequate oral hygiene and negatively affects the profile of the lower border of the reconstructed mandible (Chiapasco et al. 2006). Various methods, such as the "double-barrel fibula" (DBF) technique, on lay grafting and distraction osteogenesis (DO), have been introduced to address this problem (Levin et al. 2003; Bilbao et al. 2009).

The vascularized DBF technique was first used by Bähr et al. in 1998; and this technique achieved greater bone height and shortened the vertical distance to the occlusal plane. Mandibular defects shorter than 9.0 cm can be bridged by the double-barrel technique with the available fibula length (Bähr et al. 1998; Guerra et al. 2000; He et al. 2011). Additionally, limited studies report positive results of placing dental implants in vascularized DBF bone to achieve functional mandibular reconstruction (Chang et al. 2008, 2011; He et al. 2011). DO was another alternative to increase bone height by the creation of neoformed bone and adjacent soft tissue and was initially used in cases of vertical defect of edentulous jaws to improve bone volume for dental implant placement in 1996 (Chin & Toth 1996). It has become a widely known and effective technique to gain sufficient alveolar bone height in alveolar ridge atrophy. With this approach, bone gain in different parts of the jaws can be achieved from 8 to 10 mm (Rocchietta et al. 2008). Because of the predictable performance of DO in native bone, a few studies have focused on vertical distraction osteogenesis of fibula (VDOF) for attaining sufficient alveolar bone height before implant therapy; positive results were achieved in optimizing the implant position for ideal prosthetic rehabilitation (Siciliano et al. 1998; Chiapasco et al. 2000; Nocini et al. 2000; Marchetti et al. 2002). Although clinical data have demonstrated that bone grafting and placement of dental endosseous implants are widely accepted therapeutic options for reconstructing edentulous areas of the jaw following resective jaw surgery, there is limited information available on the clinical outcomes of dental implants in DBF and VDOF for mandibular reconstruction.

The purpose of this study was to evaluate the effectiveness of DBF and VDOF associated with dental implant treatment for mandibular reconstruction after tumor resection. Implants were restored, and treatment outcomes were measured through implant survival, implant success, bone resorption, and complications associated with DBF and VDOF.

Material and methods

Patients

The medical charts of patients who had been treated between March 2006 and May 2008 were reviewed. Patients were selected to participate if their clinical condition met the following inclusion criteria: (i) diagnosis of mandibular cyst or benign tumor, (ii) the presence of mandibular defect <9 cm in length; (iii) good oral hygiene without active periodontal disease; (iv) desire to have implant-supported fixed prostheses. Patients were excluded from participating if the following criteria were met: (i) overall general poor prognosis or systematically compromised health; (ii) current heavy smoker (>15 cigarettes per day); (iii) uncontrolled diabetes.

The study protocol was approved by the ethics committee of the Ninth People's Hospital affiliated with Shanghai Jiao Tong University, School of Medicine.

Group A: surgery and implant treatment for DBF patients

Reconstruction was performed for patients during the same surgery after a resection of the tumor in the mandible under general anesthesia. Fibula flap harvest proceeded simultaneously with the resection procedure as described previously by (He et al. 2011; Shen et al. 2012). The harvested fibula was then osteotomized into several segments to fit the mandibular defect. Before the surgery, a resin template had been made based on computerized tomographic data. The original mandibular contour was maintained by a reconstruction plate system (Synthes, Bettlach, Switzerland) according to the template; the lower layer of the fibula was fixed by the reconstruction plate to the lower border of the residual mandible, and miniplates were used for osteosynthesis between the upper layer of the fibula segments and the upper border of the residual mandible. Microvascular anastomoses were performed by magnifying optics.

Dental implants (Straumann, Basel, Switzerland) were placed in DBF bone under local anesthesia by one clinician after the healing of revascularized DBF flap. Panoramic radiographs and/or computed tomographic (CT) scans were taken before implant placement. Anti-inflammatory agents, amoxicillin (500 mg, four times a day for 7 days), and metronidazole (400 mg, three times a day for 7 days) were prescribed post-operatively. A 0.12% chlorhexidine oral rinse was also prescribed for 60 s with a frequency of 5–6 times a day for 14 days. All of the implants were observed for a healing period of 3–5 months before impressions were taken. Dental implants were restored with screw-retained fixed metal ceramic prostheses (Fig. 1).

Group B: surgery and implant treatment for VDOF patients

Patients were treated by resection of the tumor in the mandible under general anesthesia. Reconstruction was performed simultaneously in the operation with a free revascularized fibular flap. After anastomosis, the fibular bone was segmentalized vertically to follow the contour of the mandible and was fixed with titanium plates. Following the contour of the mandible, some patients underwent DO device fixation procedures at the same surgery. The bone segment to be vertically distracted was completely separated from the basal bone. The bone pedicle was connected to the lingual vessel-periosteum after horizontal osteotomy of the fibula. The DO devices (Cibei Medical Corporation, Ningbo, China; Yinghao Timing, Shanghai, China) were fixed to both the basal bone and the osteotomized segments by microplates and screws. The number of DO devices was determined by the size of defect, in general for partial mandible with deficiency distance of <10 mm, two sets of DO were used. Closure of intra- and extraoral wounds was then performed. After a 7-day period, the distraction was activated at a rate of 0.7 mm per day. After 14 days, the desired bone height (approximately 10 mm) was obtained. A solidation period of 8–12 weeks followed to obtain adequate maturation of the callus formed between the basal bone and the distracted segment (Zhang et al. 2012).

Panoramic radiographs and/or computed tomography (CT) scans were taken after the consolidation period to ensure that an adequate quality and quantity of bone was available for dental implant placement. The implants were placed in these distracted areas under local anesthesia by one clinician after a consolidation period for the DO procedure.

The post-operative medications for patients in group B were the same as for group A patients. After osseointegration was achieved, the same procedures for prostheses delivery described for group A were followed. The DO devices with osseointegration were left as implants to support fixed prostheses (Fig. 2).

All patients of group A and group B were instructed to use a sonic toothbrush (sonic toothbrush; Philips, Bothell, WA, USA) and a dental water jet to maintain adequate oral hygiene.

Outcome assessment

The follow-up examination was performed according to a standardized protocol, which

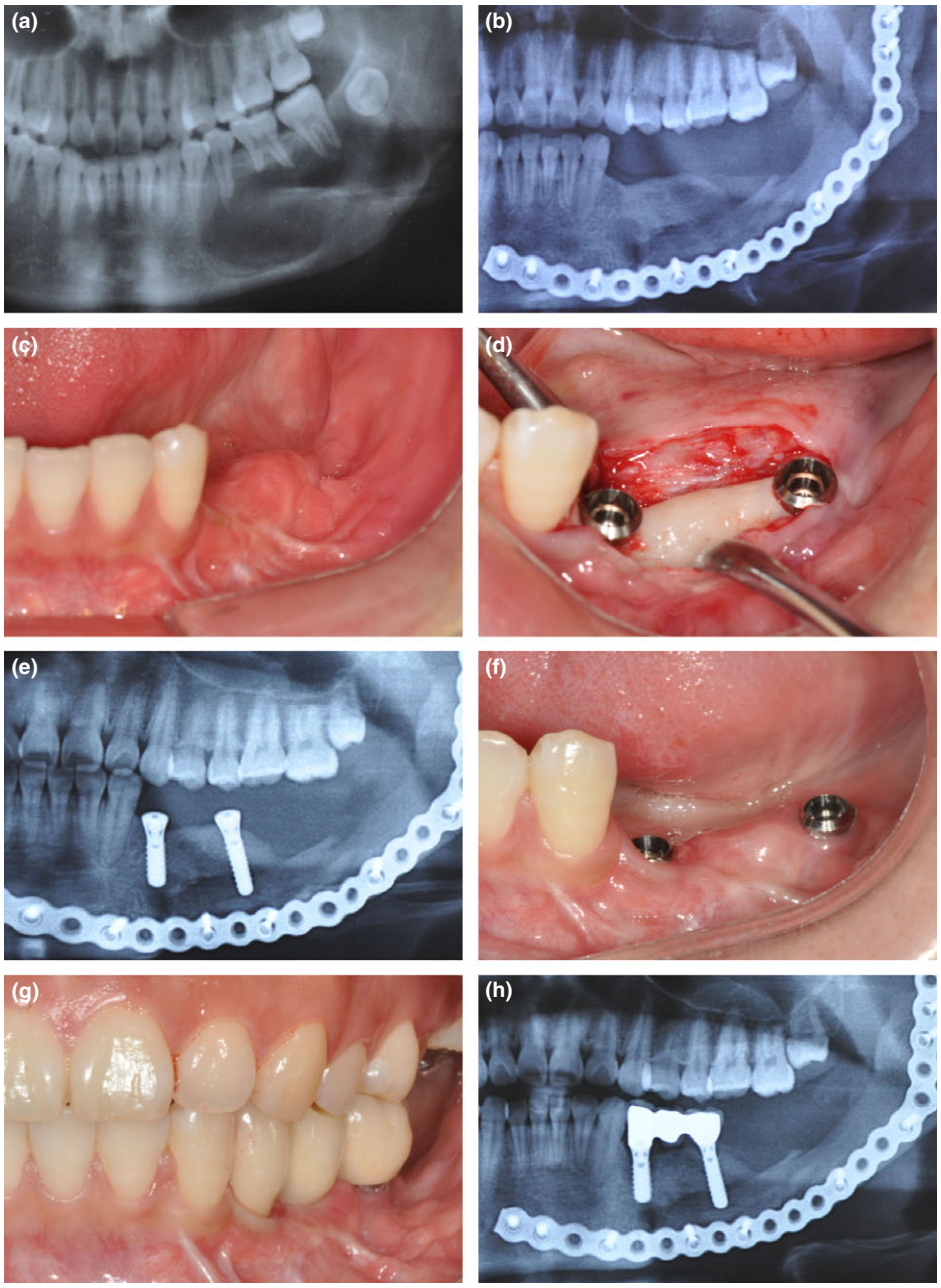

Fig. 1. (a) Panoramic radiograph showing the lesion affecting the mandibular body and the left ramus; (b) Panoramic radiograph after the tumor resection and reconstruction with DBF graft; (c) Adequate occlusal space and uneventful soft tissue healing available before implant placement; (d) Two Straumann implants were placed; (e) Panoramic radiograph immediately after implant placement; (f) The clinical status showing favorable soft tissue healing at the time of impression taken; (g) Buccal view of the prostheses; (h) Panoramic radiograph after 12 months of loading with limited peri-implant bone resorption. DBF, double-barrel fibula.

included a clinical examination and radiographic evaluations (panoramic radiographs) after delivery of the final prosthesis and annually thereafter.

Implant stability quotient

After the implants were placed, resonance frequency analysis (RFA, Osstell, Integration Diagnostics, Savadaled, Sweden) was used to measure the implant stability quotient (ISQ; Glauser et al. 2004). The transducer was hand-screwed into the implant body, as recommended by the manufacturer. Each measurement was taken twice (at the mesial, distal, buccal, and lingual aspects). These measurements were repeated when the impressions were taken and were performed by one observer.

Vertical bone height

Vertical bone height (VBH) for group A was taken from panoramic radiographs after implant placement. The distance between the upper margin of the alveolar ridge and the lower aspect of basal bone were measured around each implant. Dimensional distortion between the different panoramic radiographs was corrected with the actual implant dimensions.

Vertical bone height for group B was measured on panoramic radiographs immediately after the end of the distraction procedure. The linear measurements between the upper margin of the alveolar ridge and the lower aspect of basal bone were taken from panoramic radiographs. Measurements were performed mesial and distal to the implants in group A and distraction devices in group B. These measurements were performed twice by one observer.

Peri-implant clinical parameters

Modified Plaque Index (mPI) was measured at four points around the implants according to the following scale: 0, no plaque; 1, plaque on probing; 2, visible plaque; and 3, abundant plaque. For each implant, one MPI value was calculated based on the average of the four obtained values (Mombelli & Lang 1994).

Modified Sulcus Bleeding Index (mSBI) was measured at four surfaces around the implants. The mSBI was scored as follows: 0 = no bleeding when a periodontal probe was passed along the gingival margin adjacent to the implant, 1 = visible, isolated bleeding spots, 2 = blood formed a confluent red line on the margin, and 3 = heavy or profuse bleeding. For each implant, one mSBI value was calculated based on the average of the four obtained values ((Mombelli & Lang 1994).

Modified Plaque Index and mSBI measurements were recorded by a single experienced clinician using a plastic probe with a standardized probing force of 0.2 N.

Radiographic assessment of peri-implant bone resorption

Peri-implant bone resorption was recorded by comparing panoramic radiographs taken after implant placement, at the time of prosthesis delivery, and at the follow-up. All of the panoramic images were scanned by one operator and transferred to a computer with an image analysis programme (GE Healthcare Centricity@ v3.0, Pitttsburgh, PA, USA).

To perform accurate measurements and minimize the magnification factor inherent within panoramic radiographs, a calibration procedure based on the known implant length was performed prior to measurements being taken. Measurements between the top of the implant head shoulder and the most coronal level of the direct bone-to-implant contact were made mesial and distal to each implant. Finally, the vertical peri-implant

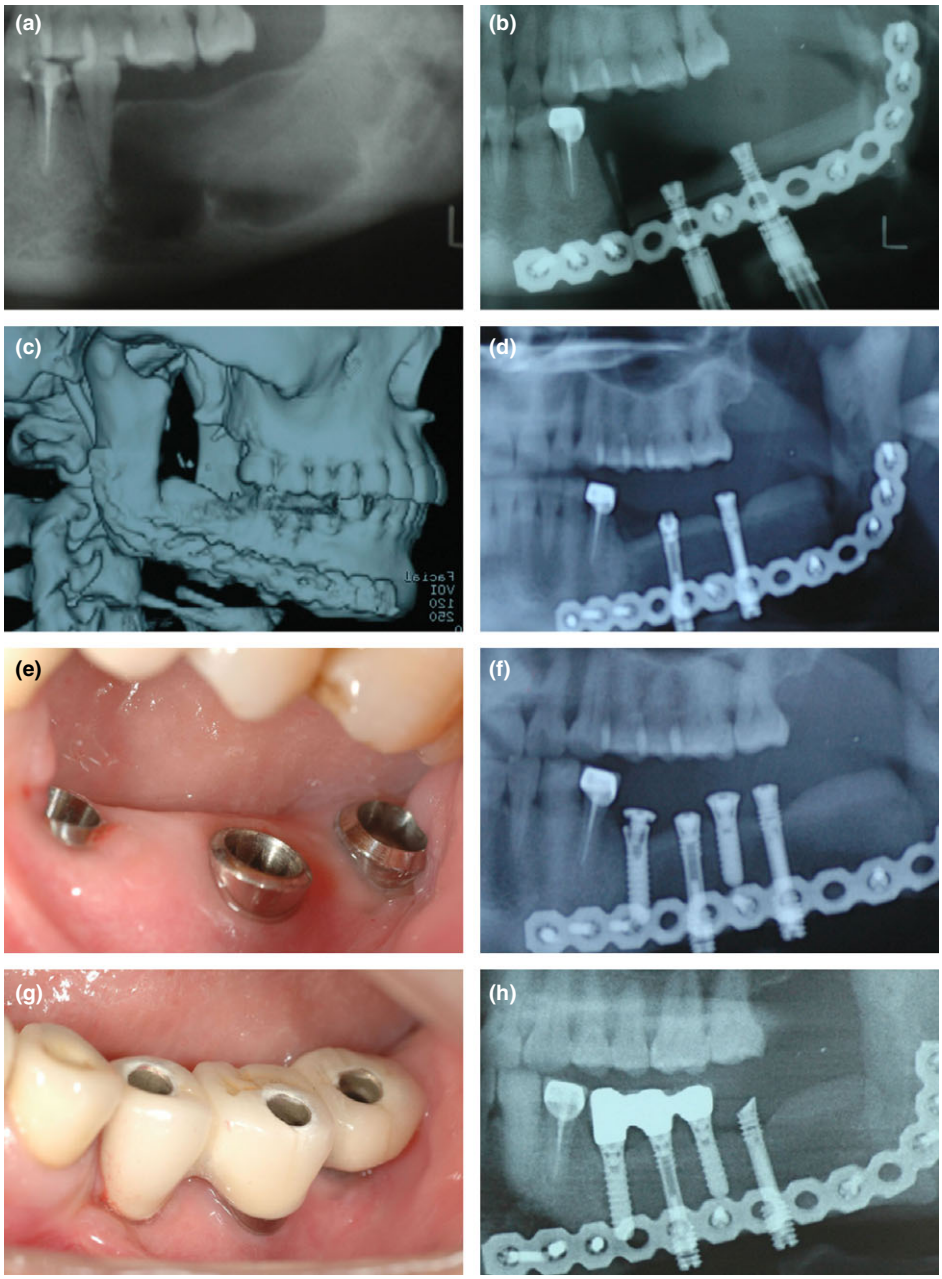

Fig. 2. (a) Panoramic radiograph showing the lesion affecting the mandibular body; (b) Panoramic radiograph right after fibular flap transfer and distraction device fixation; (c) Three-dimensional CT scan immediately after completing the VDOF procedure; (d) Panoramic radiography showing adequate bone available after the VDOF procedure; (e) Dental implants placement in VDOF bone and uneventful soft tissue healing available around implants; (f) Panoramic radiograph at the time of impression taken, showing good osseointegration of the two implants; (g) Buccal view of the prostheses, one of the DO devices with osseointegration combined with implants to withstand denture force; (h) Panoramic radiograph after 12 months of loading with limited peri-implant bone resorption. VDOF, vertical distraction osteogenesis of fibula; DO, distraction osteogenesis; CT, computed tomographic.

bone resorption values were calculated as follows: (Perez-Sayans et al. 2008)

$$\text{Real bone deficit} = \frac{\text{Actual implant length} \times \text{Radiologic bone deficit}}{\text{Radiologic implant length}}$$

The measurements were taken by two examiners, and the interexaminer reliability was assessed to ensure the accuracy of the measurements using intraclass correlation coefficient correlation test.

Implant success rates

The implant prognostic criteria were previously described by Albrektsson and Zarb. Briefly, implants were termed "successful" if the following criteria were met: the absence of mobility, the absence of paresthesia and/or pain, the absence of peri-implant pathosis or radiographic radiolucencies, and marginal bone loss <1 mm during the first year and <0.2 mm/year in the following years (Albrektsson et al. 1986).

Statistical analysis

Statistical analysis was performed by means of a SAS statistical package (SAS 9.3, SAS Institute Inc., Cary, NC, USA). Descriptive statistical analyses of peri-implant hygienic parameters and marginal bone level (MBL) were performed using the mean of the distribution, the standard deviation, the median, the minimum and the maximum. The normal distribution of the data was tested. A nonparametric mixed model was applied to compare the quantitative dependant variables (ISQ, MBL) and categorical-dependant data (mPI, mSBI) in the study. The level of statistical significance was set at $P = 0.05$.

Results

In a 3-year period (2006–2008), nine patients (six men and three women, aged between 28 and 55 years, mean age 41.1 ± 8.7 years) received DBF, and 10 patients (six men and four women, aged between 28 and 53 years, mean age 43.4 ± 7.4 years) received VDOF for mandibular reconstruction after tumor resection. Eight patients were enrolled who had either recurrent keratocysts after initial curettage therapy or keratocysts with soft tissue infiltration. The mean follow-up is 42.5 ± 4.4 months after final prosthesis delivery. The final implant-supported prostheses were restored at the Unit of Oral-maxillofacial Surgery and the Unit of Oral Implantology, Shanghai 9th People's Hospital, China. In all patients in groups A and B, microvascular fibula transfers were successful.

In group A, a total of 24 implants were placed in DBF bone (Table 1). One patient (No. 2) received four implants simultaneously at the time of the reconstruction surgery. The other 20 implants were placed in eight patients using a two-staged procedure whereby implants were placed following adequate healing (4–7 months, average 5.3 months) from the initial reconstructive surgery. One of the implants in patient No. 2 was left to "sleep" and not restored due to it being malpositioned buccally.

In group B, following the contour of the mandible in reconstructive surgery, eight patients underwent VDOF procedures. The other three patients received DO procedures after tumor resection and simultaneous

Table 1. **Clinical features of patients**

Patient no.	Sex	Age	Tumor type	Surgery site	No. of inserted implants	Implant site	Implant dimensions
Group A							
1	M	32	Ameloblastoma	43–47	3	43	4.1 × 14
						45	4.1 × 14
						46	4.1 × 14
2	M	38	Ameloblastoma	32–37	4	33	4.1 × 12
						35	4.1 × 14
						36	4.1 × 14
						37	4.1 × 14
3	M	45	Keratocyst	34–37	2	34	4.1 × 12
						36	4.1 × 14
4	M	52	Ameloblastoma	31–37	4	32	4.1 × 12
						34	4.1 × 14
						36	4.1 × 14
						37	4.1 × 14
5	F	43	Ameloblastoma	47	1	47	4.1 × 14
6	M	55	Ameloblastoma	32–37	3	33	4.1 × 14
						35	4.1 × 14
						36	4.1 × 14
7	M	40	Keratocyst	34–37	2	34	4.1 × 14
						36	4.1 × 14
8	F	37	Keratocyst	34–37	2	34	4.1 × 14
						36	4.1 × 14
9	F	28	Keratocyst	33–37	3	34	4.1 × 14
						35	4.1 × 14
						36	4.1 × 12
Mean ± SD		41.1 ± 8.7			2.7 ± 1.0		
Group B							
1	F	48	Ameloblastoma	43–47	3	43	4.1 × 12
						45	4.1 × 14
						46	4.1 × 14
2	M	45	Keratocyst	32–37	3	33	4.1 × 14
						35	4.1 × 14
						36	4.1 × 14
3	M	53	Ameloblastoma	35–45	2	33	4.1 × 14
						43	4.1 × 14
4	F	28	Keratocyst	32–37	3	33	4.1 × 14
						35	4.1 × 14
						36	4.1 × 12
5	M	36	Ameloblastoma	37–43	3	33	4.1 × 14
						36	4.1 × 14
						43	4.1 × 12
6	F	45	Keratocyst	32–37	3	33	4.1 × 14
						34	4.1 × 14
						36	4.1 × 14
7	M	43	Keratocyst	32–37	3	33	4.1 × 14
						35	4.1 × 14
						36	4.1 × 12
8	M	52	Ameloblastoma	33–47	3	33	4.1 × 14
						43	4.1 × 14
						36	4.1 × 12
9	F	43	Ameloblastoma	33–37	2	33	4.1 × 14
						36	4.1 × 14
10	M	41	Ameloblastoma	35–37	2	35	4.1 × 14
						37	4.1 × 14
Mean ± SD		43.4 ± 7.4			2.7 ± 0.5		

reconstructive surgery. The mean interval between the reconstruction and DO fixation surgery was 7 months (5–11 months). Major complications associated with DO procedures did not occur in group B. However, a few complications were observed in the DO procedure. Patient No. 2 had lingual tilting of the distracted segment. The transport segment was mobilized, and the distraction vector of the distraction rod was realigned under local anesthesia. In patient no. 3 of group B, wound dehiscence developed 8 days after surgery. The patient was then put on a regimen of rinsing with a chlorhexidaine four times a day until the dehiscence healed within 2 weeks. Distraction was continued in these two patients with no compromise of bone regeneration.

A total of 27 implants were placed in vertical DO bone following a healing (4–6 months, average 5.1 months) after solidation period (Table 1). One patient was restored by combining two implants in the DO bone with two implants in the native bone. Ten sets of DO devices for which there was no detectable clinical mobility or bone resorption were kept in place. These were combined with regular implants to withstand denture force.

After implant placement surgery, in all patients of group A and group B, healing proceeded without complications and with minimal post-operative discomfort. During 3 years of the clinical evaluation, there were no patients lost to follow-up.

ISQ

The RFA at implant placement for group A showed a mean ISQ of 78.0 ± 7.1. After the osseointegration period, all implants were stable, and the mean ISQ was 77.2 ± 6.0 for the implants. There was no significant difference in the ISQ values between the time of implant insertion and following the integration period, when impressions were made ($P = 0.51$).

For patients in group B, the mean ISQ at the time of implant placement was 69.4 ± 5.3. Following the osseointegration period, the mean ISQ values increased to 73.2 ± 6. There was a significant difference in the RFA measurements between the time of implant insertion and when the impressions were made ($P < 0.01$).

Although ISQ values recorded immediately after implant placement for both groups A and B indicate good primary stability of implants, there was a significant difference between implants placed in group A (DBF bone) relative to that in group B (VDOF bone; $P < 0.01$). Additionally, following the osseointegration period, the ISQ was higher for group A than group B and had statistically significant difference ($P < 0.01$).

Vertical bone gained (VBH)

The average VBH was 20 mm (18–23 mm) for group A and was 17 mm (16–20 mm) for group B. The measurement of VBH for group B could not be performed in three patients due to superimposition of the titanium plates, and DO devices seen on the images from the panoramic radiographs. Overall, there was a stable increase in VBH in both groups that enabled placement of dental implants.

Peri-implant clinical parameters

mPI

Table 2 shows the mean, the median, the minimum, and the maximum of mPI (%) values at prosthesis delivery and at 1-, 2-, and 3-year follow-ups for groups A and B. The mean mPI (%) values at 1 and 3 years after prosthesis

Table 2. **Peri-implant hygienic parameters (group A and group B) at prosthesis delivery and follow-up**

	Prosthesis delivery		1 year		2 year		3 year	
	Group A (n = 24)	Group B (n = 27)	Group A (n = 24)	Group B (n = 27)	Group A (n = 24)	Group B (n = 27)	Group A (n = 24)	Group B (n = 27)
mPI (%)								
Mean	10.4	11.1	12.5	13.0	20.8	14.8	25.0	14.8
Median	0	0	0	0	25	0	25	25
Min	0	0	0	0	0	0	0	0
Max	50	50	50	50	75	50	75	50
mSBI								
Mean	0.2	0.4	0.5	0.7	1.0	0.8	1.2	0.8
Median	0	0.25	0	0.5	0.5	0.5	1.0	0.5
Min	0	0	0	0	0	0	0	0
Max	1	1	2	2	3	2	3	3

delivery were 13.0 and 14.8, respectively, in group A and 12.5 and 25.0, respectively, in group B. A P value of 0.06 was detected within group A and group B in 1-year and 3-year follow-ups.

mSBI

In groups A and B, the peri-implant soft tissues appeared healthy which corresponded with mean mSBI values of 0.2 and 0.4, respectively, at the time of prosthesis delivery. The mean mSBI values at 1-, 2-, and 3-year follow-ups were 0.5, 1.0, and 1.2, respectively, in group A. There was a significant difference in the mSBI between 1- and 3-year follow-ups in group A ($P < 0.01$).

In group B, the mean mSBI was 0.7 at 1-year follow-up and at the end of the 3-year follow-up period, the mean mSBI was 0.8. No significant difference in the mSBI was observed during the follow-up period ($P = 0.71$). There was no significant difference in mSBI scores between groups A and B in the 3-year follow-up period ($P = 0.40$; Table 2).

In four cases with eight implants of group A and two cases with three implants of group B, granulomatous soft tissue was present and associated with bleeding and pain at the 1- and 2-year follow-ups. The soft tissue was removed around these 11 implants with an Er/YAG laser (Key Laser 3 Perio, KaVo, Biberach, Germany) under local anesthesia. Following this treatment, patients received individualized oral hygiene instructions. However, the granulomatous tissue of five implants in group A and 2 implants in group B reappeared 5–8 months later. In these cases, degranulation of this tissue was again performed around the implants in conjunction with free gingival grafts from tissue harvested from the palate. At the last clinical examination, there were no signs of mobility, suppuration or active peri-implant lesions around these implants.

Radiographic assessment of peri-implant bone resorption

Table 3 shows the peri-implant bone resorption for the subjects of group A and group B at the follow-up appointments. When the peri-implant bone loss data were analyzed for group A and group B, significant differences were detected between years 1 and year 3 for both groups ($P = 0.022$). No statistically significant differences were found in this study between groups A and B ($P = 0.736$).

Table 4 shows the frequency distribution of the peri-implant bone changes around the implants. Three of 24 implants in group A and four of 27 implants in group B presented peri-implant bone resorption values higher than standard values used as criteria for implant success. Thus, cumulative survival and success rates of implants placed in group A at the end of the follow-up period were 100% and 87.5%, respectively. In group B, survival and success rates were 100% and 85.2%, respectively. There was no difference in implant success rates between groups A and B.

Discussion

Oral rehabilitation using dental implants in fibula transplants has been frequently used following reconstruction of the lower jaw and has proven to be a reliable method (Taylor et al. 1989; Hidalgo 1989). However, this method may produce a height discrepancy between the native mandible and the grafted bone that leads to subsequent problems such as facial esthetics and denture rehabilitation (Frodel et al. 1993; Moscoso et al. 1994). As the longest bone that can be transferred by microsurgical techniques, the fibula has the advantage of periosteal blood supply that makes it possible for several osteotomies in the reconstruction surgery (Klesper et al. 2000). After the introduction of the technique of "double-barrel fibula bone" in 1990s, it was demonstrated to be a safe and reliable method to esthetically and functionally reconstruct mandibular defects following tumor resection (Chang et al. 2008, 2011; He et al. 2011)). However, it has been reported that bridging of mandibular defects longer than 9.0 cm is very challenging with the double-barrel technique due to the limitations of fibula length (Bähr et al. 1998; Guerra et al. 2000; Klesper et al. 2000; He et al. 2011).

Distraction osteogenesis is defined as the creation of neoformed bone and adjacent soft tissue after the gradual and controlled displacement of a bone fragment obtained from a surgical osteotomy. Histologic results have demonstrated that DO enables the formation of adequate quality and quantity of bone tissue, which could provide primary stability for implants and allow the loaded implants to withstand their biomechanical demands (Siciliano et al. 1998; Raghoebar et al. 2002). Histologic analysis of bone core biopsies from vertically distracted fibula in mandibular reconstruction confirmed that the distracted area was filled with newly formed bony trabeculae between the transported fibula and the basal segments (Cheung et al. 2013).

In our case series, DBF and VDOF were used in patients with multicystic ameloblastoma and keratocysts. Mandibular keratocysts, especially large keratocysts, were generally first treated with a less-invasive technique, such as marsupialization. However, for some ineffective or recurrent cases or with soft tissue infiltration, segmental mandibulectomy with DO reconstruction or DBF graft was performed.

Table 3. **Means, standard deviations, and ranges of peri-implant bone resorption (group A and group B) at follow-up**

Peri-implant bone resorption (mm)	1 year		2 year		3 year	
	Group A (n = 24)	Group B (n = 27)	Group A (n = 24)	Group B (n = 27)	Group A (n = 24)	Group B (n = 27)
Mean	0.42	0.51	0.58	0.65	0.68	0.71
SD	0.46	0.61	0.70	0.56	0.60	0.65
Median	0.52	0.50	0.45	0.58	0.62	0.70
Min	0	0	0	0.4	0	0.3
Max	2.0	2.2	2.3	2.4	2.7	2.6

Table 4. **Frequency distribution of peri-implant bone resorption (group A and group B) at prosthesis delivery and follow-up**

Peri-implant bone resorption (mm)	1 year		2 year		3 year	
	Group A (n = 24)	Group B (n = 27)	Group A (n = 24)	Group B (n = 27)	Group A (n = 24)	Group B (n = 27)
<0.5	11	13	15	16	18	16
0.5–1.0	9	11	5	6	1	4
1.0–1.5	3	2	0	2	1	1
1.5–2.0	0	0	3	1	1	2
2.0–2.5	1	1	1	2	2	3
>2.5	0	0	0	0	1	1

Resonance frequency analysis is a modality extensively used in clinical research to monitor implant stability due to its high reproducibility (Aparicio et al. 2006). In this study, implants in patients of group B showed ISQ values >64 at implant placement, indicative of good primary stability. Following the osseointegration phase of adaptative bone remodeling around the implants, the ISQ of 73.2 ± 6.2 in group B indicated that secondary stability was also achieved. In group A, the mean ISQ was 78.0 ± 7.1 at implant placement, which was significantly higher than that in group B. This could be explained in part due to 12 and 14 mm implants being placed which provides good anchorage in the grafted fibula bone. Chiapasco & Gatti (2004) reported in a case series that due to excellent primary stability for implants placed in grafted fibula bone, immediate loading of the implants was achievable.

There was only 1 patient in group A who received implants placed simultaneously at the time of reconstructive surgery. Chang et al. (2003) pointed out that simultaneous placement of dental implants in fibula grafts at the time of microvascular free tissue transfer affords better flexibility for re-creating an accurate interarch relationship with a simplified technique. However, immediate placement of the implants may compromise bone viability, lengthen the operative procedure or result in implant malposition (Disa et al.1999). We found it was considerably difficult to place implants in an ideal position in grafted fibula bone during primary insertion, even with the use of a surgical template. Furthermore, because of the minor gap between native bone and the grafted fibular bone and fixation plates, some implants could not be positioned with the ideal spacing in proximity to adjacent natural teeth, leading to long cantilevers as part of the prosthesis.

In the present study, the keratinized attached mucosa was removed after the tumor resection for both groups. The skin paddle and oral mucosa were used to reconstruct the intraoral lining for group A patients. In two patients of group A, palatal mucosal grafts were utilized at the second-stage implant surgery to surround and seal the implants. The first measure to avoid hypertrophy is to thin the soft tissues of the flap during grafting (Anne-Gaëlle et al. 2011). So we improved the design of the free vascularized fibula flap by not using a skin paddle and by decreasing the thickness of the soft tissue for six patients in group B. Oral hygiene instructions, which included the use of a sonic toothbrush and a dental water jet for daily maintenance, were given to all of the patients. Instead of using a traditional design, we used one that left sufficient space around the implants for the interdental brushes to provide effective plaque control in the marginal areas.

At prosthesis delivery and 1-year follow-up, the low mean plaque levels (<20%) indicated a good level of oral hygiene for groups A and B. However, mPI and mSBI of group A increased to 25% and 1.2 at 3-year follow-up. In 1- and 2-year follow-ups, we observed that four patients with eight implants in group A and two patients with three implants in group B exhibited an inflammatory response of the peri-implant mucosal tissue and formation of granulomatous tissue around the implants, particularly on the lingual surfaces. A similar tissue response in these types of cases has been described by others (Chang et al. 2008; Ciocca et al. 2008; Wu et al. 2008). It has been suggested that the extraoral derived soft tissues around these implants is not suitable and might respond adversely in the oral environment due to the inadequate integrity of the peri-implant attachment apparatus (Chiapasco et al. 2006; Chang et al. 2008). Other considerations include prosthetic designs and anatomical limitations created following these procedures (i.e., high level of the floor of the mouth), which could cause difficulties in maintaining adequate oral hygiene. Additionally, the soft tissue coverage of group A was often thicker (because of the fibula osteoseptocutaneous flap) leading to relatively deeper probing depths. The thick soft tissue around implants was very different than that of normal healthy gingiva and more mobile than the attached gingiva of the oral mucosa, proving less conducive to oral hygiene. For this reason, probing depths measures normally a part of any implant assessment were not used in the evaluation between group A and group B (Blake et al. 2008).

Although the incidence of the peri-implant inflammatory response in group A (8/24) was higher than that in group B (3/27), there was no significant difference of marginal bone loss between groups A and B at 3-year follow-up. No implant was removed due to excessive bone loss. It has been demonstrated previously that the fibular bone graft can be resistant to bone resorption (Chiapasco et al. 2006; Gbara et al. 2007; Chang et al. 2008). In our study, despite having a higher incidence of a peri-implant inflammatory response, patients who received the double fibula graft (group A) were more resistant to crestal bone resorption over time.

An important consideration of our study is that due to anatomical limitations post-resective and recontructive surgery (i.e., high floor of the mouth), standardized periapical radiographs could not be obtained in the majority of patients, As such, we used panoramic radiographs to assess peri-implant bone resorption, as has been described by others. To most accurately measure in this way, eliminating the magnification inherent within panoramic radiography, a calibration procedure based on the known implant length was performed (Gbara et al. 2007; Perez-Sayans et al. 2008). Nonetheless, measurement error from panoramic radiographs could still be a limitation of our evaluation.

Conclusion

On the basis of the study of 19 patients who received a total of 51 implants the following observations were made:

The reconstruction of the mandible with DBF flap or VDOF flap, in combination with dental implant therapy, was considered a valuable and predictable treatment option for patients following tumor resective surgery. Compared with implants placed in VDOF bone, implants placed in DBF bone had a relative higher incidence of a peri-implant inflammatory response. Finally, DBF bone was more resistant to peri-implant bone resorption processes than VDOF bone during functional loading.

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