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Nonvascularized Iliac Bone Grafts for Mandibular Reconstruction – Requirements and Limitations

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Abstract. *Background: Treatment of intraoral malignant tumors often leads to continuity defects of the mandible. Whereas the use of free vascularised flaps has shortcomings regarding donor site morbidity and a worse-fitting bone geometry, the nonvascularized iliac crest graft could be an alternative option. The purpose of this study was to describe the treatment outcome with nonvascularized iliac crest grafts over a 10-year period and to determine possible limitations of their use. Patients and Methods: Eigthy-four patients with bicortical nonvascularized iliac crest grafts for mandibular reconstruction were examined at least one year after reconstruction. Patients' records and the radiological and/or surgical data were analyzed. Results: Sixty-three patients (75%) showed complete healing, in 20 patients the treatment was not successful and in one patient the treatment result was unclear. Interestingly, comparing the successfully and the unsuccessfully treated patients, only the irradiation dose played a crucial role. Neither defect length nor defect localisation, nor time interval between resection and reconstruction were statistically significant parameters in graft success. Comparing only patients with malignancies, the non-irradiated patients had a higher success rate (77.3%). Conclusion: The nonvaslcularized iliac crest graft seems to be a reasonably reliable treatment option for reconstruction of mandibular defects up to about 5-6 cm in size. Radiotherapy is a strong confounder reducing the success rate. Necessary constraints are sufficient soft tissue conditions. However, primary reconstruction by free flaps (e.g. fibula flap) has a higher success rate in literature and should be preferred whenever possible.*

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The treatment of intraoral squamous cell carcinoma, ameloblastoma, severe osteomyelitis or even large cystic lesions often includes the resection of parts of the lower jaw. These segmental bone defects initially cause a disruption of the muscular attachments, impair mastication and speech, and can lead to inadequate lip closure. Thus, functional as well as esthetic problems affect such patients, resulting in a poor quality of life (1). Consensus exists among surgeons on the necessity for reconstruction of the bony defect of the mandible.

However, besides the appropriate time point for reconstruction (immediately or secondary) various types of bone transplants are also currently debated. Such transplants can be classified as vascularized bone flaps and nonvascularized bone flaps. Although vascularized bone flaps offer the most complete means of reconstruction for mandibular defects (2, 3) they have some shortcomings regarding donor site morbidity and extended duration of the surgical procedure (2, 4). In addition, the revascularized fibular free flap (the most commonly used free flap for mandibular reconstruction) leads to lower values for quality of life regarding chewing and swallowing compared to nonvascularized iliac crest transplants (5), and there is less precision in achieving bone symmetry (6). Another disadvantage for some free bone flaps (*e.g.* of scapula and fibula) is the small vertical bone height making oral rehabilitation (*e.g.* by dental implants) difficult (7).

Due to its nonvascularized nature, the success rate for iliac crest graft decreases with the defect length (4, 5). It remains unclear which defect size is most suitable for nonvascularized bone grafts. Whereas the lack of soft tissue is a firm exclusion criterion for the use of nonvascularized bone grafts (at least if

no additional flap should be raised), the role of irradiation in choosing between various transplants remains unclear.

The purpose of this study was to analyze the success rate of nonvascularized iliac crest bone grafts for the mandibular reconstruction with respect to the various confounders (*e.g.* defect size, radiation, *etc.*).

Materials and Methods

Between 1996 and 2005, 84 patients with segmental defects of the mandibular bone underwent bone reconstruction with nonvascularized iliac crest grafts. The bicortical grafts were raised from the anterior border of the iliac bone and fixed with titanium plates (Stryker, Freiburg, Germany). Mandibular reconstruction was performed using the extraoral approach. When radiotherapy was performed, patients were treated before reconstruction. Besides the evaluation of the patient's data (defect size, radiation, age, gender, pathologic disorder, defect localization, time interval between resection and reconstruction, cause for mandibular resection) the success of the reconstruction was determined as follows.

All patients were examined at least one year after reconstruction. About six months (mean 6.6 months) after reconstruction, in many cases, the titanium plates were removed. Success was defined according to van Gemert and co-workers (2): maintenance of bone continuity and complete consolidation with absence of infection on intraoperative examination or panoramic radiograph. The defect localization was determined similar to Shibahara and colleagues (8).

For statistical analysis, the software SPSS® 18.0 was used. To detect any statistical differences, the Kruskal-Wallis test, the Mann-Whitney-*U* test, as well as the Chi-square test, were performed. A *p*-value below 0.05 was considered as being statistically significant.

Results

Sixty of the 84 treated patients were men and the mean age of the whole group was 54 (standard deviation 14.6) years. The time interval between the resection and the reconstruction was 22 (standard deviation 26) months. The high standard deviation is the consequence of the large range from 0 months (immediate reconstruction) to 128 months (reconstruction after repeated tumor resection and radiotherapy). The average defect size for the whole group was 4.9 (standard deviation 2.1) cm. The resection of an intraoral squamous cell carcinoma (60%) was the predominant reason for the bone resection (Table I). About one third of the defects were located in the lateral segment of the lower jaw between the foramen mentale and the angle (Table II). Thirty-seven patients received radiotherapy before the reconstruction of the mandible was performed. The mean irradiation dose was 54 Gy. In 49 patients the decision whether the transplanted bone showed complete healing or not was made by direct examination of the mandible during the removal of the plates. In 35 patients this decision was made by clinical and radiological examination. Sixty-three patients (75%) showed complete healing and in 20 patients the treatment was not successful, and in one patient the treatment result was unclear. Neither defect length nor defect localization, nor time interval between resection and reconstruction were statistically significant by parameters (Table III). However, there were significant differences for irradiated patients regarding the diagnosis, the time interval between resection and reconstruction (38 standard deviation 30 months (irradiated) *vs.* 10 standard deviation 11 months (no radiotherapy)) and the type of plate used for fixation of the iliac crest graft. Moreover, the defect size was significantly greater (5.6 standard deviation 1.8 cm) than in the non-irradiated group (4.4 standard deviation 2.2 cm) (Table IV). In the irradiated group, the patients with successful healing had received a slightly, but significantly lower irradiation dose than the patients with healing problems (Figure 1). Taken together, irradiation seems to be the predominant factor for successful healing in the whole group (Table V). For patients with malignant tumors (n=57), the success rate for irradiated patients (71.4%) was lower than that of non-irradiated patients (77.3%) (Table VI). These two groups differ not regarding the defect size but the time interval between primary jaw resection and secondary reconstruction (Table VI). Surprisingly, even 16 patients with successful healing suffered complications. Most frequently, infection of the plates was seen (Table VII). In every case, these infections were initially treated with antibiotics and, when there was no recovery, the plates were removed.

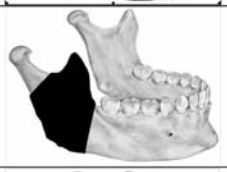
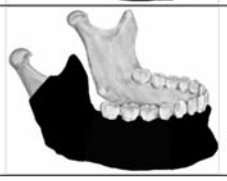
Table I. *Diagnosis leading to resection of the mandible.*

Diagnosis	n. (%)
Squamous cell carcinoma	50 (60)
Cyst	15 (18)
Osteomyelitis	1 (1)
Ameloblastoma	8 (10)
Other malignant tumor	7 (8)
Pseudarthrosis	1 (1)
Other diagnoses	2 (2)

Discussion

Radiotherapy before mandibular reconstruction is significantly associated with a worse outcome for transplantation of a nonvascularized iliac crest graft. Whereas the non-irradiated patients had a success rate of 78%, the patients who underwent radiotherapy presented a significant lower success rate of 70%. This is also true regarding patients with malignant tumors alone. These two groups of head and neck tumor patients (irradiated *vs.* non-irradiated) differ regarding the time interval until reconstruction. This can be explained by the longer treatment and recovery time of irradiated patients. However, rates for both are in line with various published reports indicating success rates of between 46% and 100% (2, 4, 9, 10). Recently, van Gemert reported a 76% success rate in 91 patients with segmental defects of the mandible. Interestingly,

Table II. *Defect localization*.

Defect localization		Total n. (%)	Successful healing n. (%)
Between the *foramina mentales*		12 (14)	8 (67)
Between *foramen mentale* and angle		26 (31)	22 (85)
Ramus mandibulae		10 (12)	8 (80)
Anterior and lateral mandible		15 (18)	11 (73)
Ramus and lateral mandible		19 (23)	13 (68)
Anterior mandible until *ramus*		2 (2)	1 (50)

radiotherapy had no statistically significant influence on the outcome in their study. This could be explained by the fact that all irradiated patients received 20 sessions of hyperbaric oxygen therapy prior to reconstruction and an additional 10 sessions postoperatively (2). Although the use of hyperbaric oxygen therapy is disputed, there are some reports supporting this treatment modality for other bone diseases (11). Moreover, hyperbaric oxygen therapy seems to be the only known treatment which is able to reverse the radiation changes in the tissue at least in part (12). Maurer and co-workers also reported a decreased success rate in irradiated patients, of 56% compared to 71% in non-irradiated (13), and Adamo and Szal reported an incidence of 81% for complications in previously irradiated patients (14). In our investigation, irradiated patients and those who did not undergo radiotherapy differ with regard to the time interval between resection and reconstruction and the type of plates used (reconstruction plates *vs*. mini plates).

Table III. *Analysis of factors in the comparison of successful and unsuccessful transplants in patients undergoing mandibular reconstruction*.

Criteria	*p*-Value
Age	0.332
Gender	0.489
Diagnosis	0.642
Defect localization	0.425
Kind of plate	0.164
Defect size	0.669
Time until reconstruction	0.746
Irradiation dose	0.034

This can be explained by the fact that in this group, a malignant tumor (most frequently a squamous cell carcinoma) was the diagnosis. This leads to a slightly greater defect size and a

Table IV. *Comparison of irradiated with not irradiated patients.*

Criteria	*p*-Value
Age	0.836
Gender	0.211
Diagnosis	0.001
Defect localization	0.136
Kind of plate	0.016
Defect size	0.018
Time until reconstruction	<0.001

Table V. *Transplant success rate in irradiated and non-irradiated patients.*

Patient group	No.	Defect size cm (mean±sd)	Success n, (%)
Non irradiated	47	4.4±2.2*	37 (79)*
Irradiated	37	5.5±1.8*	26 (70)*
All	84	4.9±2.1	63 (75)

*Statistically significant difference ($p<0.05$).

Table VI. *Comparison of transplant success between irradiated and non-irradiated patients with head and neck tumor.*

	No.	Success rate n, (%)	Time interval months	Defect size cm
Irradiated	35	25 (71.4%)	39±31*	5.7±1.7
Non-irradiated	22	17 (77.3%)	19±9*	5.3±2.2

*Statistically significant difference ($p<0.01$).

Table VII. *Complications during healing or leading to failure of mandibular reconstruction**.

	Healing	Failure	Unclear
No. patients	63	20	1
No. complications	47	0	0
Fracture of plates	4	1	0
Infection of plates	10	17	0
Exposed plates	2	3	1
Other	3	4	0

*Due to the fact, that some patients showed multiple complications, the number do not sum to the total number of patients.

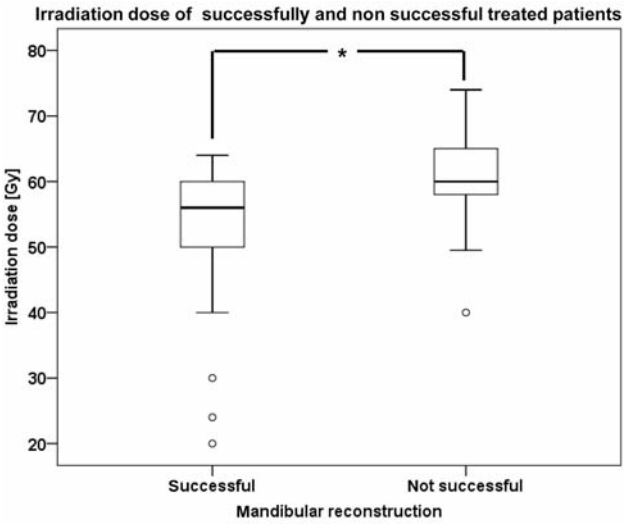


Figure 1. *Influence of Irradiation dose on treatment success. Note the slight but statistically significant difference (*p<0.05) between success and failure in irradiated patients regarding the irradiation dose.*

more frequent use of reconstruction plates. The frequent use of reconstruction plates in greater defects is also documented by other authors (13). In contrast to van Gemert, the predominant complication we found was not intraoral wound dehiscence, but infection of the plate. The reason for this is probably that in our investigation, an external approach was used exclusively (2). Regarding the fracture of plates, our numbers are in line with the literature (8). Surprisingly, four out of the five fractures were observed in the healing group. This means that fracture of the plates, although it is unpleasant for the patient, does not affect the outcome. The low number of plate fractures demonstrates the need for mandibular reconstruction with bone grafts. In patient collectives who in the majority received no bone reconstruction, the complication rate is much higher, as reported by various authors (13, 15, 16). An alternative way to reconstruct the mandible is the use of free vascularized flaps. Actually, the vascularized fibula osteoseptocutaneus flap seems to be the first option for most mandibular reconstructions (17, 18). However, Sieg and colleagues reported serious donor site morbidity such as disturbance of efferent (27%) as well as afferent nerves (48%) (19). Regarding the recipient site, Wei and co-workers reported a 90% success rate using the vascularized fibula flap in patients with mandibular defects ranging from 7 to 14 cm in size (18). Other authors reported a similar success rate in primary reconstruction (20-22), adding by way of explanation that minor complications are common and should not be neglected because they may lead to devastating consequences (20). Another question discussed in the literature is the influence of the defect localization on the outcome. Whereas van Gemert et al. found a significantly worse impact of symphyseal involvement on the result (2), in our study, there was only a trend but not a significant difference. Unfortunately, the defect size is not reported in their study. Thus, although there is some evidence for worse healing when the anterior mandible is involved, there might be additional confounders (*e.g.* defect size).

In conclusion, the nonvascularized iliac crest graft seems to be a reasonably reliable treatment option for reconstruction of mandibular defects up to 5-6 cm in size. Radiotherapy is a strong confounder reducing the success rate. Moreover, this effect seems to be dose-dependent. Intensity-modulated radiotherapy could diminish these side-effects (23). Necessary constraints are sufficient soft tissue conditions. In cases of larger bone defects or lack of soft tissue, free vascularised composite grafts (*e.g.* the vascularized fibula osteoseptocutaneus flap) should be the first choice. However, primary reconstruction by free flaps (*e.g.* fibula flap) show higher success rates in the literature and should be preferred whenever possible.

In the future, tissue engineering strategies might be able to substitute the transplantation of autologous bone, at least for smaller defects (24, 25)

Competing Interests

All Authors declare that there are no competing interests regarding the interpretation or presentation of the data or results.

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