Reconstruction of the resorbed maxilla with iliac crest or calvarial bone grafts

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CHAPTER 7

General discussion and conclusions

Patients in need for an implant retained denture due to severe resorption of the edentulous jaw often require bone reconstruction for reliable implant placement. For years, anterior iliac crest has been widely used to perform these reconstructions. Calvarial bone grafts are a possible alternative. The PhD research in this thesis aimed to compare the clinical, radiological, and histological outcomes of anterior iliac crest and calvarial bone graft harvesting.

Patient reported outcomes and morbidity

The current thesis revealed that bone graft harvesting surgery from both the calvarial bone, and the anterior iliac crest is associated with high patient appreciation (Chapter 2, 3 and 4). When interpreting the outcomes, several considerations can be made. It has been shown that the construct of patient satisfaction is most strongly affected by fulfillment of expectations and experiences of the patient[1]. The high overall satisfaction observed in the studies described this thesis, also may reflect high fulfillment of expectations, and limited negative experiences for patients. Another factor affecting the patient's satisfaction with harvesting surgery, is satisfaction with other aspects of the treatment[1]. For instance, when patients are highly satisfied with the improvement of their denture function, differences in satisfaction with donor site related outcomes might be overshadowed[2]. Thus, expectations, experiences, and acceptance of other aspects of the treatment might affect the patient reported satisfaction with bone graft harvesting surgery. Therefore, to enable truly patient's appreciation, sources of dissatisfaction like postoperative pain, sensory alterations, esthetic outcomes, and complications have to be assessed as well. The studies in this thesis reflected that postoperative pain was low for both donor sites with a slight favor for calvarial harvesting (Chapter 2 and 3). Also, independently from the donor site, sensory alterations were limited and mostly not noticed by patients, esthetic outcomes were generally not bothersome to patients (Chapter 2 and 4) and complication rates were low (Chapter 3).

For anterior iliac crest harvesting, pain is postulated as a major source of gait disturbances. It is the most frequently mentioned drawback of anterior iliac crest harvesting[3,4]. Moreover, pain and gait disturbances have been reported as a major source of dissatisfaction for patients[5]. In attempt to limit these complaints, several authors studied the mechanism and possible measures to avoid pain following anterior iliac crest harvesting. The pain is either musculoskeletal or neurogenic, secondary to the stripping of abductors from the ilium or neurogenic secondary to sensory nerve injury. Recommendations to reduce morbidity of iliac crest harvesting, i.e., a skin incision 2 cm medially to the iliac crest with an appropriate length for adequate exposure; avoidance of excessive stretching of the tissues and damage to the superficial sensory nerves; respect for fascial planes and minimal dissection of muscles and harvesting only the required amount of bone, leaving distance from the anterior superior iliac spine, are shown to reduce donor-site complications, in particular reduce the incidence and severity of pain[3]. Further

reduction in pain and gait disturbances can be achieved by treating the cortices following the harvest, e.g by using bone wax or other hemostatic materials[3,4,6], or post-harvest reconstruction of the iliac crest. These adjustments in operative techniques are advised to reduce postoperative gait disturbances.

Several studies have focused on which factors predict the level of postoperative pain. In general surgery, pain severity and duration were found higher in patients with younger age, female sex, smoking habits, history of depressive symptoms, anxiety symptoms or difficulties, presence of preoperative pain, especially in the same region, and the use of preoperative analgesia[7-10]. However, the clinical relevance of these associations is unclear[11] as the effects on pain following iliac crest harvesting are limited. Another factor that has been associated with pain[7-9,12,13] and adverse events[14,15] following surgical treatments, is BMI. When iliac crest is harvested, elevated pain and gait disturbances in patients with higher levels of BMI were demonstrated as well[13,16]. This probably results from compromised accessibility of this donor site, thereby strengthening the above-described mechanism of stretching of the tissues causing postoperative pain and gait disturbances. These patients may profit from choosing another donor site like calvarial bone.

Sensory disturbances[3,4,17] and unfavorable esthetics are frequently mentioned drawbacks from harvesting extra-oral bone. For calvarial and anterior iliac crest, the impact of these outcomes seems limited (Chapter 2). In fact, sensory alterations are mostly temporary and barely noticed by patients, and patients reported to appreciate the cosmetic outcomes at donor site. To further optimize the outcomes of harvesting surgery with regards to sensory alterations and esthetics at donor site, several technical steps have been suggested. Sensory disturbances following iliac crest harvesting can be avoided by limiting direct trauma of the lateral cutaneous nerve[3,4,17]. When harvesting from the calvarium, a parasagittal incision and limited use of electrocautery have been proposed to limit sensory nerve damage[18-20]. Considering contour alterations, calvarial harvesting is associated with more prone deficits[21-23], which is probably due to the superficial location of the harvesting site. To limit the contour alterations for both harvesting locations, it is advised to reconstruct the defect with an osteoconductive biomaterial[24,25]. With regards to esthetic outcomes following calvarial harvesting, alopecia is reported as well. This late complication may be avoided by using a 30° angle incision to the follicles[19], a very low use of electrocoagulation[19,20], and the use of low tension sutures[26,27].

Other potential sources of dissatisfaction by patients includes complications associated with harvesting calvarial or anterior iliac crest grafts. While pain and gait disturbances do frequently occur, but are mostly temporary, most other complications can be considered minor[3,4,18,19,28-36], in particular for calvarial harvesting. In fact, a previous study on subclinical complications following calvarial harvesting, such as punctate intracranial bleeding or cerebral contusions,

did not identify such sequelae on computed tomographic scans[37]. However, when it comes to major complications, trepanation of the skull when harvesting calvarial bone might occur with significant sequelae such as sagittal sinus injury, brain injury, cerebrospinal fluid leak and meningitis as a result[19,29,30,38]. However, cases of dura exposure are generally quickly recognized and treated adequately[28-30], thus the patients do not suffer from permanent neurologic sequelae. Several authors declare that safe and successful calvarial harvesting is highly dependent on the training, technique[30,39,40] and expertise of the surgeon [28-30,39,40], but recent developments in the harvesting technique drastically have reduced, or perhaps even eliminated, this risk[16,41,42].

Specific major complications when harvesting anterior iliac crest bone include deep infection, iliac fracture, sacroiliac joint injury, arterial, nerve or ureteral injuries, meralgia paresthetica, hernias, pelvic instability and major hematomas[3,4,43]. Incidence of fracture of the iliac crest is low (0.7-1.2%) and invasive treatment is not needed in most cases[3,4]. Generally, patients recover well from these fractures.

To conclude from the above, particularly harvesting calvarial bone seems to be accompanied by a favorable outcome when applying the modified technique, and anterior iliac crest harvesting seems to be accompanied with similar results with mostly mild and temporary effects.

Microscopic properties of anterior iliac crest and calvarial bone grafts

The current comparison of anterior iliac crest and calvarial bone grafts by means of imaging technology (histology/histomorphometry and microCT) revealed differences in terms of quantity (volume) and quality (bone structure): both fresh harvested and incorporated calvarial grafts were denser and more contained a greater portion of cortical bone compared to the highly cancellous anterior iliac crest (Chapter 6). The incorporation and resorption rates of both graft types reflect these differences in micro-architecture.

In general, cancellous bone is very osteogenic, easily revascularized, and rapidly incorporated at the host site due to the large surface area covered with dormant and active osteoblasts[44-46]. Indeed, the highly cancellous anterior iliac crest grafts demonstrated these properties (Chapter 6). Calvarial grafts exhibited adequate incorporation of the grafted bone as well, despite their low proportion of cancellous bone. A drawback of highly cancellous bone grafts is the lack of mechanical strength, demonstrated by the decrease in bone volume in the anterior iliac crest grafts[46,47]. Cancellous bone exhibits high induction and production of new bone, thus providing early stability at the recipient site, but the space maintaining ability of cancellous bone is limited and this overrules its biologic activity, resulting in more volume loss of the grafted site over time[47-49].

With regards to cortical bone in general, it is often stated that revascularization is hampered by the dense architecture of the graft[44-46]. Also, a relatively scarce number of endosteal cells is available for the formation of end-to-end anastomoses. Thus, to enable revascularization and the recruitment of osteoblasts, incorporation of cortical bone is initiated by osteoclasts instead of osteoblasts[44-46]. Indeed, the cortical parts of anterior iliac crest grafts showed decrease of the bone percentage after four months incorporation. The cortical parts of calvarial grafts showed high percentages of bone even after four months healing, despite the thicker and denser cortical layer of calvarial bone.

The findings on microarchitecture and bone preservation correspond to features associated with the embryogenic origin of calvarial and iliac crest grafts, that is, intramembranous and enchondral origin, respectively[17,50-53]. Intramembranous bone is known to exhibit high bone preservation compared to enchondral bone[54-59]. Some state this results from the microscopic architecture of the tissue[58], others suggested differences in vascularization networks[59]. However, recent in vitro analysis has proposed a key role for osteocytes in bone regeneration[54-57,60]. Osteocytes account for 90–95% of all bone cells and they are thought to sense mechanical loads and accordingly transmit the signals to osteoblasts and osteoclasts through the osteocyte network, and thus regulate bone remodeling [58,59,60,61]. Likely, intramembranous osteocyte networks have a better bone preserving and regenerating ability in case of reconstruction of severe defects of the jawbone prior to implant placement. The current findings as well as previous reports[61] correspond to the findings from in vitro[54,56,57] and animal studies[48]: cortical bone of calvarial grafts showed a high efficiency in bone remodeling (demonstrated in Chapters 2 and 6) and are minimally resorbed, and show high viability and good incorporation. Additionally, the mesenchymal calvarial grafts exhibit more space maintaining properties, resulting in a higher bone volume preservation compared to enchondral bone grafts.

Autologous bone grafts versus bone tissue engineering

Bone graft harvesting surgery bears risks of donor site morbidity and complications. Therefore, several attempts have been made to optimize bony reconstructions by means of bone tissue engineering. A variety of materials have been used over time to substitute bone tissue, such as animal derived substitute materials (xenografts)[47,62-64]. Clinical studies on these xenografts to reconstruct severe defects are lacking. Histologic studies reported that xenografts demonstrate poor absorption and vascularization[47,64-67]. Poor absorption and vascularization hampers replacement of the graft by newly formed bone and compromise bone quality of the reconstructed jaw. In case of small reconstructions, such shortcomings are compensated by the regenerative capacities of the native bone. For large (horizontal and vertical) defects, this still must be shown. For example, only under the condition of mixation with autogenous bone and application of a membrane to cover the graft site, onlay grafting with bovine bone

mineral block was successful for reconstructions of intermediate defects of the anterior maxilla in partially dentate patients, however reconstructions with bovine bone alone failed[68]. Thus, reconstructions of large defects with bovine bone alone seems challenging with the current techniques and there is still an important place for autologous bone grafts.

Some authors have pointed out the clinical advantages of combining regenerative procedures with platelet-rich fibrin (PRF) to enhance bone[69]. However, a systematic review on the application of PRF in the dental field found very little to no data available directly investigating the effects of PRF on new bone formation in horizontal/vertical bone augmentation procedures[69]. Others mention the lack of evidence for using such substances in large defects as well[70-73]. Furthermore, several approaches have been made to optimize the vascularization in bone regeneration attempting to improve graft incorporation and bone regeneration. Human adipose tissue-derived stromal vascular fraction (SVF) and microvascular fragments (MF) are promising examples here. However, the usability of such substances in case of large bony defects has not been determined[70-72].

Future studies

The current thesis aimed to compare the augmentation of the maxilla using either calvarial or anterior iliac crest bone grafts from a clinical, radiological, and histological perspective. To further optimize the reconstruction of the severely resorbed maxilla for prosthetic rehabilitation, future studies are needed. The following topics have still to be addressed:

- Long term evaluations of the clinical outcomes of anterior iliac crest and calvarial bone harvesting to reconstruct large defects, including patient reported outcomes with a specific focus on sources of dissatisfaction;
- Long term evaluations of microstructure and volume maintaining properties of the bone grafts;
- More basic experiments on osteocyte level to elucidate the mechanisms of bone preservation between anterior iliac crest osteocytes and calvarial osteocyes
- Economic aspects of both procedures such as intraoperative costs and postoperative infirmity.

Long term (>5 years) RCTs are needed to compare the clinical bone volume maintenance and implant survival. Also, since postoperative complaints can affect patient reported satisfaction, studies should also assess patient satisfaction. Special attention should be placed at the impact of dissatisfying factors like pain, sensory disturbances, esthetic outcomes and complications bearing consequences for patients.

Long term evaluations of the microarchitecture and volume maintaining properties of the grafts are needed. The current results suggest that calvarial grafts are more favorable in terms of bone quality and bone quantity, but Carinci et al[74] postulated that the outcomes might approximate each other over time[74]. As the course of bone quality and quantity affects implant survival and prosthetic functioning, long term studies comparing the regeneration of maxillary bone augmented with either anterior iliac crest and calvarial bone grafts can add in selecting the most reliable and predictable treatment planning for a particular case.

Considering economic outcomes, several aspects are frequently discussed. First, it is often stated that anterior iliac crest harvesting is economically more favorable from a surgical perspective as a two-team approach can be employed, thereby reducing the duration of the surgery. On the contrary, the costs associated with a longer period of impaired independency in daily activities or unemployment of the patient following iliac crest bone harvesting[75-77] might outweigh this benefit. In other words, calvarial harvesting requires some extra surgical time, but patients recover more quickly. Some reports on the costs of anterior iliac crest harvesting for reconstruction of the severely resorbed edentulous maxilla exist[22,78], but not for calvarial bone graft harvesting. Also, a fair comparison is hampered as the management of inpatient care, including time management of operation rooms and nursing wards depend to a major extent on local standards and facilities. To weigh the costs of anterior iliac crest and calvarial bone grafts, future studies should be performed in which the sources of bias are reduced for example by performing a randomized controlled trial.

CONCLUSION

Clinical and histological studies have demonstrated that a severely resorbed maxillary alveolar ridge can be augmented effectively and predictably with both calvarial or anterior iliac crest bone grafts. The morbidity of a second surgical site required for both graft types should be weighted correctly: patients' report high satisfaction on various parts of the procedure and donor site related morbidity is temporary. However, the early postoperative complaints are a bit lower for calvarial bone, but one-year results are comparable. It thus can be concluded that calvarial grafts are a viable alternative to anterior iliac crest bone grafts for reconstruction of the severely resorbed edentulous maxilla.

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