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

Wortmann, Dagmar

DOI:
10.33612/diss.196167204

CHAPTER 1

Introduction

Bone graft surgery

Bone grafting and bone repair has been on people's minds for hundreds of years. In the old testament, it was Adam's rib that was grafted to create Eve. In the Greek myths the gods used ivory to reconstruct a young man's shoulder[1,2]. In 1668, a traumatic defect in a soldier's cranium was repaired by a bone graft taken from the scalp of a dog scalp [1,2]. During that century, the first publications on bone structure and bone healing arose. Bone grafting further developed, with a first focus on what we now call xenografts: animal derived tissue. An early report on autologous bone grafting, meaning the source of the graft is the same person, dates from 1821, when an autograft bone implant was used to replace parts of a skull surgically[1,2]. Several years later the German anatomist and surgeon Julius Wolff brought science on bone grafting to a next level and developed a law stating that bone in a healthy person or animal will adapt to the loads under which it is placed. If loading on a particular bone increases, the bone will remodel itself over time to become stronger to resist that sort of loading[3]. In the twentieth century, bone grafting gained popularity and knowledge on bone graft healing increased further. An important precondition for the successful introduction of bone grafting in the maxillofacial region, was the discovery of penicillin and the subsequent development of other types of antibiotic treatments[2]. This development stimulated a number of surgeons in the fifties and sixties to reconstruct the atrophic mandible with autologous bone grafts. With regards to bone grafting in maxillofacial surgery, a publication arose on the osteoplastic substitution in cases of maxillomandibular defects using parts of the rib[4] in 1908. Clementschitsch had succeeded in reconstructing an atrophic maxilla with a bone graft via an transoral approach in 1948[2] and several others followed. In the mid-1950s, Dr. Paul Tessier further improved the surgical correction techniques for craniofacial deformations. Throughout the 1960s and 1970s, he developed the methods among which the use of autogeneous bone grafts instead of silicone or acrylic to modify skull and facial contours[5] Ever since, bone grafting has developed into a unique scientific endeavor that is essential to many surgical disciplines, including maxillofacial surgery.

Several considerations that must be taken into account when planning for a bone grafting procedure from various donor sites[8]. These include donor site morbidity and its effect on the patient's quality of life, inflicting the patient's acceptance and satisfaction about the procedure[6-8]. In the earliest reports on bone grafts, the success of a bone graft was determined by its macroscopic volume and stability with regards to applied stresses, but nowadays the dynamic and biologic structure of a bone graft is considered very important. Thus, a successful bone graft becomes incorporated, revascularizes and assumes the form desired. Also patient' appreciation of the procedure are no longer seen as of secondary importance. Therefore, the success of bone grafting should be assessed in light of its burdens and the final treatment outcome in general.

Bone graft surgery and implant-supported prosthesis

During the last decades, partial or total edentulism correction by means of implant-supported prostheses has become a reliable routine[9-12]. Unfortunately, severe bone defects, arising from long-standing edentulism, periodontal disease or trauma sequelae, may significantly hamper the placement of oral implants. In these cases, difficulties are caused by the proximity of anatomical structures such as the inferior alveolar nerve, the maxillary sinus and the nasal floor and the absence of sufficient bone volume to placed implants with adequate primary stability in a prosthetically driven position. Also, the arisen unfavorable vertical and/or horizontal intermaxillary relationship may compromise the final prosthetic outcomes[13-16]. To create more favorable conditions in these situations, different bone reconstructive techniques have been proposed, including guided bone regeneration[17-19], maxillary sinus floor elevation[20,21], distraction osteogenesis[22,23] and onlay grafting with autogenous bone blocks[6,13,24-28].

Maxillary reconstruction with bone grafts represents a versatile and very well-documented procedure which allows the correction of most defects in different clinical scenarios [7,11,13,14,24,29]. Autogenous bone remains the gold standard for maxillary reconstruction of severe bone defects as it provides copious amounts of bone material and it possesses the three classic qualities of the ideal graft, viz. osteoinduction, osteoconduction and osteogenesis. To harvest autogenous bone grafts, several sites are in use which include the retromolar region, the mandibular symphysis region, the tuberosity region, the anterior and posterior iliac crest, and the calvarium. In case of large defects, where intraoral donor sites may be not sufficient in terms of bone quantity, the anterior and posterior iliac crest and the calvarium are frequently used donor sites[13,24,30-36].

Anterior iliac crest bone graft harvesting has been a highly popular donor type for decades[1,7,37]. In the past, the posterior aspect of the ilium was frequently chosen as it contains twice as much bone as the anterior site. The surgical complexity is similar for the anterior and posterior approach, and for both approaches there exist a risk of damaging adjacent structures such as nerves and muscles. Both sites are associated with donor site related morbidity. For anterior iliac crest harvesting, this includes pain, sensory disturbances and gait problems which are generally temporary[6,38]. Morbidity is less common when the posterior approach is used compared to the anterior approach, and gait problems are uncommon, however the sequela are potentially more severe due to the proximity of the sacroiliac joint and the sciatic nerve[39] . Fractures of the crest are more frequently seen in the anterior approach, however these fractures remain stable and heal spontaneously in most cases without further complication[40]. On the contrary, graft harvesting related fractures of the posterior iliac crest often require further surgical intervention and might cause functional disability[40]. An important drawback from using posterior ilium is that surgery cannot be performed simultaneously with the grafting in the oral cavity. The patient must be turned during the operation. The anterior iliac crest can be harvested using a two-team

surgical approach to simultaneously harvest the bone and perform the augmentation surgery, thereby reducing surgery time. As anterior iliac crest site is easily accessible, associated with less severe morbidity and can provide considerable amounts of cortical and cancellous bone, this site is often preferred.

More recently, the calvarium demonstrated to be an excellent donor site for intra-oral grafting as well. Ever since the first publications arose[36,41], calvarial bone has showed reliable results in terms of bone quantity due to its rich cortical component and the limited resorption rate. Also, favorable results have been reported on implant survival rates over time[12] and morbidity[13,42,43]. However, some limitations were observed, including acceptance by patients, morbidity related to the procedure and potential complications such as meningitis, accidental dural exposure and tear, entry into the sagittal sinus and brain damage caused by the osteotome used for harvesting the graft[14]. A recent adjustment in the harvesting technique has limited the complication risk dramatically, however[42,44,45].

Choosing the ideal bone graft

When choosing the donor site for an individual patient, one aims to choose the ideal bone graft. As described by Zouhary[37], the ideal bone graft material for dental implant reconstruction should demonstrate the following six features.

- The graft material should have the structural integrity to maintain space during bone ingrowth, graft consolidation and maturation, and implant osseointegration;
- The graft material should be able to promote cells at the recipient site to form bone within the graft;
- The graft material should be able to be resorbed, remodeled and replaced as the viable native bone;
- The resultant augmented maxilla or mandible should be stable over time after implant restoration and functional loading;
- The material should have ease of harvest and placement to minimize procedure length and subsequently maximizing potential for graft success while minimizing patient morbidity;
- The graft should have a repeatable and predictable outcome.

Furthermore, there are several additional factors to consider when choosing the right donor site among which the quantity and type (cortical versus cancellous). These factors should guide the choice of graft material. Exclusively after these factors have been carefully considered in light of the patient's comorbidities and expectations, it should be decided which site(s) are appropriate as a donor site for each particular patient and application.

In case of pre-implant maxillary reconstructions needing large grafts due to severe bone loss, the iliac crest and calvarium bone have been demonstrated to fulfill these criteria to a high extend[35-37,46]. When choosing between both grafts, detailed knowledge on both types is required. Despite several clinical studies on both donor types, detailed up-to-date reports on patient appreciation, postoperative pain and morbidity are scarce and comparative studies are lacking[12,47,48]. Several studies reporting a high overall satisfaction exist for both donor types[33,43,48-51] , however, patients' opinions on the donor site contour changes, scar formation, problems in gait and sensibility alterations are assessed in various ways and conflicting results are reported[49,52] .

Apart from the clinical outcomes of the harvesting surgery, knowledge on the material properties and biological behavior of the graft are needed to decide between the two bone types. Evaluation of qualitative and quantitative factors, such as relative volumetric changes, mineral density and maturation of the graft provide insight into the long-term outcomes of the reconstruction. In this respect, the incorporation of calvarial bone has been frequently questioned as revascularization might be low due to its dense cortical structure. However, several clinical studies demonstrated a higher resorption rate of anterior iliac crest bone grafts compared to calvarial bone graft[33]. The three-dimensional volume reduction after reconstructions with iliac crest bone ranges from 24% [33] after 6 months to 60%[14] after one year. When calvarial bone grafts are used, the resorption is reported to be 0-15%, viz., 8.44% after 6 months[33] and 10%[51] to 19.2%[7] after one year. The numbers of resorption reported are in coherence with evaluations by means of imaging technology such as histology/histomorphometry and microCT[8,45], however comparative studies on graft incorporation following augmentation of the severely resorbed edentulous jaw are lacking.

Objectives

This thesis aims to compare anterior iliac crest and calvarial bone grafts for alveolar reconstructions of the severely resorbed maxilla in terms of clinical and patient reported outcomes, and radiological, and histological features. The specific aims were:

- To review the literature regarding the patient reported outcomes associated with anterior iliac crest or calvarial bone graft harvesting (Chapter 2).
- To assess the biomaterial properties and bone remodeling of calvarial bone grafts as a function of time in patients needing augmentation of the severely resorbed edentulous maxilla (Chapter 3).
- To compare patient satisfaction and patient-reported morbidity following anterior iliac crest and calvarial bone graft harvesting in patients needing augmentation of the severely resorbed edentulous maxilla (Chapter 4).

- To compare donor site related morbidity following anterior iliac crest and calvarial bone graft harvesting in patients needing augmentation of the severely resorbed edentulous maxilla (Chapter 5).
- To compare histological and micro-CT changes of anterior iliac crest and calvarial bone grafts used for augmentation of the severely resorbed edentulous maxilla (Chapter 6).

REFERENCES

1. Blitch EL, Ricotta PJ. Introduction to bone grafting. J Foot Ankle Surg 1996:35(5):458-462.
2. Hjørting-Hansen E. Bone grafting to the jaws with special reference to reconstructive preprosthetic surgery. A historical review. Mund Kiefer Gesichtschir 2002:6(1):6-14.
3. Oppenheimer AJ, Tong L, Buchman SR. Craniofacial Bone Grafting: Wolff's Law Revisited. Craniomaxillofac Trauma Reconstr 2008:1(1):49-61.
4. Meeder PJ, Eggers C. The history of autogenous bone grafting. Injury 1994:25:2.
5. Watts G. Paul Tessier. Lancet. 2008:372(9636):368.
6. Nkenke E, Neukam FW. Autogenous bone harvesting and grafting in advanced jaw resorption: morbidity, resorption and implant survival. Eur J Oral Implantol 2014:7:S203-217.
7. Sakkas A, Wilde F, Heufelder M, Winter K, Schramm A. Autogenous bone grafts in oral implantology-is it still a "gold standard"? A consecutive review of 279 patients with 456 clinical procedures. Int J Implant Dent 2017:3(1):23.
8. Kamal M, Gremse F, Rosenhain S, et al. Comparison of Bone Grafts From Various Donor Sites in Human Bone Specimens. J Craniofac Surg 2018:29(6):1661-1665.
9. Becktor JP, Isaksson S, Sennerby L. Survival analysis of endosseous implants in grafted and nongrafted edentulous maxillae. Int J Oral Maxillofac Implants 2004:19(1):107-115.
10. Esposito M, Grusovin M, Felice P, Karatzopoulos G, Worthington H, Coulthard P. The efficacy of horizontal and vertical bone augmentation procedures for dental implants - a Cochrane systematic review. Eur J Oral Implantol 2009:2(3):167-184.
11. Van Velzen FJ, Ofec R, Schulten EA, Ten Bruggenkate CM. 10-year survival rate and the incidence of peri-implant disease of 374 titanium dental implants with a SLA surface: A prospective cohort study in 177 fully and partially edentulous paients. Clin Oral Implants Res 2015:26(10):1121-1128.
12. Chiapasco M, Tommasato G, Palombo D, Scarnò D, Zaniboni M, Del Fabbro M. Dental implants placed in severely atrophic jaws reconstructed with autogenous calvarium, bovine bone mineral, and collagen membranes: A 3- to 19-year retrospective follow-up study. Clin Oral Implants Res 2018:29(7):725-740.
13. Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in implant dentistry. Int J Oral Maxillofac Implants 2009:24:s237-259.
14. Chiapasco M, Zaniboni M, Boisco M. Augmentation procedures for the rehabilitation of deficient edentulous ridges with oral implants. Clin Oral Implants Res 2006:17:s136-159.
15. Slot W, Raghoebar GM, Cune MS, Vissink A, Meijer HJA. Four or six implants in the maxillary posterior region to support an overdenture: 5-year results from a randomized controlled trial. Clin Oral Implants Res 2019:30(2):169-177.
16. Stellingsma K, Raghoebar GM, Visser A, Vissink A, Meijer HJ. The extremely resorbed mandible, 10-year results of a randomized controlled trial on 3 treatment strategies. Clin Oral Implants Res 2014:25(8):926-932.
17. Chiapasco M, Abati S, Romeo E, Vogel G. Clinical outcome of autogenous bone blocks or guided bone regeneration with e-PTFE membranes for the reconstruction of narrow edentulous ridges. Clin Oral Implants Res 1999:10(4):278-288.

18. Lang NP, Hämmerle CHF, Brägger U, Lehmann B, Nyman SR. Guided tissue regeneration in jawbone defects prior to implant placement. Clin Oral Implants Res 1994:5(2):92-97.
19. Simion M, Jovanovic SA, Tinti C, Benfenati SP. Long-term evaluation of osseointegrated implants inserted at the time or after vertical ridge augmentation. Clin Oral Implants Res 2001:12(1):35-45.
20. Pjetursson B, Tan W, Zwahlen M, Lang NP. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. J Clin Periodontol 2008;35(8):216-240.
21. Pjetursson B, Rast C, Bragger U, Schmidlin K, Zwahlen M, Lang NP. Maxillary sinus floor elevation using the (transalveolar) osteotome technique with or without grafting material. Part I: Implant survival and patients' perception. Clin Oral Implants Res 2009;20(7):677-676.
22. Chiapasco M, Romeo E, Casentini P, Rimondini L. Alveolar distraction osteogenesis vs. vertical guided bone regeneration for the correction of vertically deficient edentulous ridges: A 1–3-year prospective study on humans. Clin Oral Implants Res 2004;15(1):82-95.
23. Jensen OT, Ringeman JL, Cottam JR, Casap N. Orthognathic and Osteoperiosteal Flap Augmentation Strategies for Maxillary Dental Implant Reconstruction. Oral Maxillofac Surg Clin North Am 2011;23(2):301-319.
24. Chiapasco M, Zaniboni M, Rimondini L. Autogenous onlay bone grafts vs. alveolar distraction osteogenesis for the correction of vertically deficient edentulous ridges: a 2-4-year prospective study on humans. Clin Oral Implants Res 2007;18(4):432-440.
25. Sbordone L, Toti P, Menchini-Fabris G, Sbordone C, Guidetti F. Implant survival in maxillary and mandibular osseous onlay grafts and native bone: a 3-year clinical and computerized tomographic follow-up. Int J Oral Maxillofac Implants 2009;24(4):695-703.
26. Schwartz-Arad D, Ofec R, Eliyahu G, Ruban A, Sterer N. Long Term Follow-Up of Dental Implants Placed in Autologous Onlay Bone Graft. Clin Implant Dent Relat Res 2016;18(3):449-461.
27. Smolka W. Calvarial grafts for alveolar ridge reconstruction prior to dental implant placement: an update. Oral Maxillofac Surg 2014;18(4):381-385.
28. Von Arx T, Buser D. Horizontal ridge augmentation using autogenous block grafts and the guided bone regeneration technique with collagen membranes: A clinical study with 42 patients. Clin Oral Implants Res 2006;17(4):359-366.
29. Aghaloo TL, Misch C, Lin GH, Iacono VJ, Wang HL. Bone Augmentation of the Edentulous Maxilla for Implant Placement: A Systematic Review. Int J Oral Maxillofac Implants 2016;31:s19-s30.
30. Carinci F, Farina A, Zanetti U, et al. Alveolar ridge augmentation: a comparative longitudinal study between calvaria and iliac crest bone grafrs. J Oral Implantol 2005;31(1):39-45.
31. Gutta R, Waite PD. Outcomes of calvarial bone grafting for alveolar ridge reconstruction. Int J Oral Maxillofac Implants 2009;24(1):131-136.
32. Iizuka T, Smolka W, Hallermann W, Mericske-Stern R. Extensive augmentation of the alveolar ridge using autogenous calvarial split bone grafts for dental rehabilitation. Clin Oral Implants Res 2004;15(5):607-615.
33. Mertens C, Decker C, Seeberger R, Hoffmann J, Sander A, Freier K. Early bone resorption after vertical bone augmentation--a comparison of calvarial and iliac grafts. Clin Oral Implants Res 2013;24(7):820-825.

34. Quiles JC, Souza FA, Bassi AP, Garcia IR, Jr., Franca MT, Carvalho PS. Survival rate of osseointegrated implants in atrophic maxillae grafted with calvarial bone: a retrospective study. Int J Oral Maxillofac Surg 2015;44(2):239-244.
35. Tessier P, Kawamoto H, Matthews D, et al. Taking bone grafts from the anterior and posterior ilium--tools and techniques: II. A 6800-case experience in maxillofacial and craniofacial surgery. Plast Reconstr Surg 2005;116 Suppl:25S-37S.
36. Tessier P, Kawamoto H, Posnick J, Raulo Y, Tulasne JF, Wolfe SA. Taking calvarial grafts, either split in situ or splitting of the parietal bone flap ex vivo--tools and techniques: V. A 9650-case experience in craniofacial and maxillofacial surgery. Plast Reconstr Surg 2005;116 Suppl:54S-71S.
37. Zouhary KJ. Bone graft harvesting from distant sites: concepts and techniques. Oral Maxillofac Surg Clin North Am 2010;22(3):301-316.
38. Dimitriou R, Mataliotakis GI, Angoules AG, Kanakaris NK, Giannoudis PV. Complications following autologous bone graft harvesting from the iliac crest and using the RIA: a systematic review. Injury 2011;42:S3-15.
39. Nkenke E, Weisbach V, Winckler E, et al. Morbidity of harvesting of bone grafts from the iliac crest for preprosthetic augmentation procedures: a prospective study. Int J Oral Maxillofac Surg 2004;33(2):157-163.
40. Nocini PF, Bedogni A, Valsecchi S, et al. Fractures of the iliac crest following anterior and posterior bone graft harvesting. Review of the literature and case presentation. Minerva Stomatol 2003;52(10):441-448, 448-452.
41. Tessier P. Autogenous bone grafts taken from the calvarium for facial and cranial applications. Clin Plast Surg 1982;9(4):531-538.
42. Putters TF, Schortinghuis J, Vissink A, Raghoebar GM. A prospective study on the morbidity resulting from calvarial bone harvesting for intraoral reconstruction. Int J Oral Maxillofac Surg 2015;44(4):513-517.
43. Kuik K, Putters TF, Schortinghuis J, van Minnen B, Vissink A, Raghoebar GM. Donor site morbidity of anterior iliac crest and calvarium bone grafts: A comparative case-control study. J Craniomaxillofac Surg 2016;44(4):364-368.
44. Schortinghuis J, Putters TF, Raghoebar GM. Safe harvesting of outer table parietal bone grafts using an oscillating saw and a bone scraper: a refinement of technique for harvesting cortical and "cancellous"-like calvarial bone. J Oral Maxillofac Surg 2012;70(4):963-965.
45. Monje A, Monje F, Galindo-Moreno P, Montanero-Fernandez J, Suarez F, Wang HL. Microstructural and densiometric analysis of extra oral bone block grafts for maxillary horizontal bone augmentation: a comparison between calvarial bone and iliac crest. Clin Oral Implants Res 2014;25(6):659-664.
46. Sittitavornwong S, Gutta R. Bone graft harvesting from regional sites. Oral Maxillofac Surg Clin North Am 2010;22(3):317-330, v-vi.
47. Sakkas A, Schramm A, Winter K, Wilde F. Risk factors for post-operative complications after procedures for autologous bone augmentation from different donor sites. J Craniomaxillofac Surg 2018;46(2):312-322.

48. Donovan MG, Dickerson NC, Hanson LJ, Gustafson RB. Maxillary and mandibular reconstruction using calvarial bone grafts and Branemark implants: a preliminary report. J Oral Maxillofac Surg 1994;52(6):588-594.
49. Cricchio G, Lundgren S. Donor site morbidity in two different approaches to anterior iliac crest bone harvesting. Clin Implant Dent Relat Res 2003;5(3):161-169.
50. Mertens C, Steveling HG, Seeberger R, Hoffmann J, Freier K. Reconstruction of severely atrophied alveolar ridges with calvarial onlay bone grafts and dental implants. Clin Implant Dent Relat Res 2013;15(5):673-683.
51. Lenzen C, Meiss A, Bull HG. Augmentation of the extremely atrophied maxilla and mandible by autologous calvarial bone transplantation. Mund Kiefer Gesichtschir 1999;3(3):S40-42.
52. Reissmann DR, Dietze B, Vogeler M, Schmelzeisen R, Heydecke G. Impact of donor site for bone graft harvesting for dental implants on health-related and oral health-related quality of life. Clin Oral Implants Res 2013;24(6):698-705.