Comprehensive evaluation of factors affecting autogenous bone graft integration in the maxillofacial region

PhD thesis

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Introduction

The modern era of dental implantology dates back to 1965. In that year Per-Ingvar Brånemark inserted the first machine turned, cylindrical titanium implant and described the term of osseointegration. In the beginnings minor and major bone deficiencies of the alveolar process meant an absolute contraindication of dental implant placement; nevertheless, nowadays –as a benefit to modern reconstructive techniques- practically every bone deficiency caused by physiological resorption, accidents or resective surgeries can be reconstructed.

The augmentation of bone, especially the jaw bones and the alveolar process is one of the most dynamically developing areas of medical sciences. This is proven by the fact that the second most frequently transplanted human tissue after blood is bone. In the USA approximately 220.000 extensive grafting procedures are performed utilising autogenous bone. The estimated number of these procedures reaches 2.2 million per year in the field of orthopediatric-, neuro- and in oral and maxillofacial surgery with the total cost of more than 2.5 billion US Dollars.

In plastic surgical reconstructions usually the solely reestablishment of bony contours supporting soft tissues is sufficient. On the other hand in implant dentistry and in the field of alveolar reconstructions it is inevitable to use techniques resulting in new bone harmoniously integrated into neighbouring tissues.

To augment minor bony defects several natural and synthetic bone substitutes are commercially available. Modern bone substitutes exhibit increasingly favourable biological properties. The biocompatibility, remodelling and integration capacity of these materials is getting similar to autogenous bone, despite being only osteoconductive.

Despite the fact that the history of bone grafting dates back more than 100 years (and has underwent significant development ever since) up to now it has not been possible to avoid autogenous bone grafting. Even today the autogenous bone graft is the only bone substitute, which has osteoconductive, osteoinductive and also osteogenic characteristics.

For the reconstruction of jawbones small and larger amounts of autogenous bone can be harvested from several intra- and extraoral donor sites. Choosing the donor site depends on the size and the localisation of the defect (for maxillary sinus augmentation spongious bone is sufficient, nevertheless for vertical augmentation of the lower jaw usually cortical bone is preferred).

Autogenous bone grafts - although derived from the same individual – despite of carefully applied surgical protocols might be prone to complications during healing, get infected and be lost.

During the planning phase of reconstructive surgeries frequency of donor site morbidity and severity of possible complications is individually considered.

During the presentation of the results research data of numerous autogenous bone grafting procedures performed at the Department of Oro-Maxillofacial Surgery and Stomatology, Semmelweis University will be shown. The causes of impaired donor- and recipient site healing and treatment possibilities will be summarised. A retrospective analysis was made to determine the rate of integration of different autogenous bone grafts.

In the second part of our investigations we studied the various branching patterns of mandibular canals, which is very important during the planning phase of surgeries on the lower jaw and can be hardly detected on traditional X-rays. The present thesis discusses the significance of anatomic variations in alveolar reconstructive surgery, which have not been described so far in the international literature.

Aims

1. To analyse and evaluate anatomic variations of the mandibular canal affecting bone grafting or dental implant placement.
2. To compare radiographical findings of the Department of Oro-Maxillofacial Surgery and Stomatology, Semmelweis University with the international literature.
3. To compare the radiographical data with direct measurements on desiccated cadaver mandibles.

4. To evaluate the integration of autogenous bone grafts harvested from different extraoral donor sites, to clinically evaluate graft remodelling.
5. To determine optimal donor sites for the augmentation of different defects of the alveolar process.
6. To compare the morbidity of the most frequently used extraoral donor sites.
7. To evaluate the influence of different autogenous bone grafting procedures on postoperative life quality.

Methods

Investigation of the mandibular canal pathway

46 desiccated cadaver mandibles provided by the Department of Anatomy, Histology and Embriology, Semmelweis University and 1.000 orthopantomograms provided by the Department of Oro-Maxillofacial Surgery and Stomatology, Faculty of Dentistry, Semmelweis University were analysed.

In case duplicate canals were detected adjacent to the mental foramen during macroscopical examination, i.e. two entrances were present, canals were probed using 0.2 mm diameter blunt wires, subsequently X-rays were taken.

- mandible specimens with probes inserted were radiographically analysed by lateral cephalometric X-ray scans
- polistyrol stands were fabricated for mandible fixation, subsequently orthopantomograms were taken white probes in situ
- horizontal relationship of mandibular canals in the mandibular corpus were investigated utilising occlusal x-rays

Evaluation of graft integration

Our investigations were performed on data obtained from 110 patients, who were treated at the Department of Oro-Maxillofacial Surgery and Stomatology, Faculty of Dentistry, Faculty of Dentistry, Semmelweis University over a time period of 33 months (March 2007-November 2009) by bone grafting procedures with extraoral donor sites (sinus floor elevation, onlay block augmentation, simultaneous onlay block augmentation and sinus floor elevation, secondary osteoplasty).

At our Department we utilised iliac crest, tibial proximal epiphysis and calvarial bone grafts.

Distribution of patients in the morbidity evaluation

	Augmentation of the maxillary sinus	**Onlay augmentation**	**Onlay + sinus augmentation**	**Secondary osteoplasty**
Tibia (n=39)	39	0	0	0
Iliac crest (n=62)	0 (26)	0	26	36
Calvaria (n=9)	0	9	0	0

bone harvesting from the iliac crest the anterior superior iliac spine was explored in all cases. In the tibia we used the medial exploration technique of the epiphysis. Calvarial bone grafts were harvested from the parietal tuberosity. All surgeries were performed in intratracheal narcosis.

Evaluation of donor site morbidity

In the donor site morbidity and postoperative complaints evaluation 110 patients were included (62 iliac crest, 31 proximal epiphysis of the tibia and 9 calvarial grafts).

Postoperative pain related to donor sites was monitored for 2 weeks. For this purpose we introduced a 3-grade scale based on the Numeric Pain Scale, this was used by patients to rate daytime pain intensity at the end of the day. The 1st grade indicated slight, the 2nd grade moderate and the 3rd grade high levels of pain. We also observed the incidence of postoperative complications such as haematoma, seroma, fracture or paraesthesia.

During the planning phase of alveolar process reconstructions it is essential to perform radiographic analysis (orthopnatomograms, CBCT scans) beside clinical examination, fabrication of plaster casts and diagnostic wax-ups.

CBCT scans were taken of the augmented areas 1 week as well as 16-20 weeks after surgery.

The aim of the CBCT analysis was to measure density changes of transplanted autogenous bone blocks. These measurements were used to gather information about the grade and dynamics of bone remodelling. Differences in resorption rate, changes in density (HU: Hounsfeld Unit) and size of bone grafts was compared based on CBCT scans in each group.

Results

Investigation of the mandibular canal pathway

Prevalence rate of duplicate canals was reported to be significantly different in various publications. During enosseal implant placement and augmentation in the molar, premolar region as well as bone grafting from the retromolar region prevalence of additional canals should be considered. Thus, unfavourable complications related to frequently occurring permanent injury of previously discussed anatomic landmarks can be avoided.

Compared to the prevalence rate of duplicate canals in orthopantomograms, a significantly higher number of such anatomic variations was found by macroscopic examination of mandible specimens. These figures vastly exceed the rate of radiographically detected cases reported in the literature.

Based on our findings, it can be hypothesised that the actual occurrence of such anatomic variations of duplicate canals is more frequent compared to radiographic observations.

Comparison of the investigation of mandibular canals in desiccated mandible specimens compared to measurements taken on orthopantomograms

ANATOMIC CHARACTERISTICS OF THE MANDIBULAR CANAL !	PREVALENCE RATE !
No duplication !	37/46 !
Unilateral duplicate canals reaching molars, originating from a common mental foramen !	4/46
Duplicate canals starting from the mental foramen, divided by a septum in the first section, merging in the molar region !	2/46 !
2.5 cm long canal starting from an accessory aperture behind the mental foramen !	1/46 !
Three separate canals on the left mandibular ramus with separate entrances !	1/46 !
Accessory canal over the main canal, laterally crossing its pathway, ending at the mesial root of the second molar !	1/46 !

Evaluation of graft integration

The quality of transplanted grafts can be clinically evaluated after the remodelling phase (5-6 months on average). This is performed during re-entry, simultaneously with implant placement and retrieval of bone block fixating screws. The success of transplantation can be influenced by multiple factors.

Following observations were made during clinical examination of bone blocks harvested from different donor sites.

Iliac crest grafts are a result of encondral ossification, their D3-D4 bone quality is consistent after remodelling following augmentation.

Iliac grafts containing large amounts of spongious bone are rapidly vascularised due to their physical conditions and consistency. Thus, re-entry can be safely performed 5 months after transplantation, enosseal implants can be placed.

The proximal epiphysis of the tibia contains spongious bone, which was mixed with bone substitute particles in a 1:1 ratio, which was used to augment the maxillary sinus in all cases.

Placement of dental implants (to augmented sites) was performed 5-6 months postoperatively. After exploring the surgical site, clinically the corticalisation of the previous bony fenestration, covered by a resorbable collagen membrane was observed. Generally, during drilling well-vascularised, bleeding bone of D3 quality was found.

Calvarial grafts, as a result of their density are slowly vascularised and remodelled, therefore, according to our experiences, 6 months healing is required after grafting from the calvaria. In cases of horizontal augmentation, if bone grafting was performed within 6 months, healing time was insufficient for remodelling. In these cases, transplanted bone grafts were easily detached during implant placement. Considering these factors, optimal timing of implant placement is a crucially important factor.

Based on our investigations we found that to augment the alveolar process with autogenous bone grafts we achieved optimised results with the following protocol:

1. If 8-10 cm^3 of spongious bone was needed, bone was harvested from the proximal epiphysis of the tibia
2. If more than 10 cm^3 spongious bone was required, the iliac crest was used as donor site
3. In horizontal and vertical augmentations localised to an area of 2-3 missing teeth retromolar bone blocks were utilised

4. In onlay block augmentations exceeding the area of 3 missing teeth, if spongious bone was also needed, the iliac crest was preferred

5. In extended lateral or vertical augmentations (exceeding the area of 3 missing teeth) most favourable clinical bony conditions were obtained by using calvarial grafts

Evaluation of donor site morbidity

Processing morbidity data from chosen donor sites (iliac crest, proximal epiphysis of the tibia, calvaria) delivered following results:

Summary of extraoral donor site morbidity

The least		Postoperative pain			Haematoma	Seroma	Paraesthesia	Fracture of the iliac crest
		minimal	moderate	severe				
	Tibia (n=39)	5 cases (four days) 12.8 %	3 cases (two days) 7.69 %	1 case (one day) 2.56 %	1 case 2.56 %	0 0 %	0 0 %	
	Iliac crest (n=62)	25 cases (two weeks) 40.32 %	31 cases (two weeks) 50 %	6 cases (2-3 days) 9.68 %	1 case 1.61 %	2 cases 3.22 %	1 case 1.61 %	1 case 1.61%
	Calvaria (n=9)	1 case 11.1 %	0 0 %	0 0 %	0 0 %	0 0 %	0 0 %	

The least postoperative complaints and complications were observed in cases treated with calvarial grafts, followed by the proximal epiphysis of the tibia and finally the iliac crest.

Conclusions

1. We were the first internationally to publish original data on the investigation of anatomic variations of the mandibular canal in desiccated mandibles, comparing these findings with results of radiographical analysis.

2. During macroscopic examination of mandible specimens we observed a significantly higher number of variations compared to data in international literature and to our own data on the prevalence of duplicate canals detected in a large number of analysed orthopantomograms. Therefore, we can rightfully hypothesise that the real prevalence rate of such clinically significant anatomic variations is higher compared to eventually radiographically detected canal duplications.

3. We observed and were the first to report on a three-branch mandibular canal, which was previously not described in international literature.

4. We introduced the harvestment technique of spongious bone from the proximal epiphysis of the tibia with a medial approach into surgical practice in Hungary.

5. We were the first in Hungary to investigate and analyse morbidity rates associated to the three most frequently used extraoral donor sites to augment the alveolar process. The present findings enable clinicians to choose optimal donor sites needed for the reconstruction of various alveolar defect types.

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