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Maxillary sinus floor elevation surgery

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Chapter 1

Introduction and Aim of the Study

Introduction

Edentulous patients with a severely resorbed maxilla frequently complain of ill fitting upper dentures. The continuing process of resorption, related to loss of teeth in the upper jaw, may eventually result in poor denture retention. Moreover, patient related factors such as an extreme gagging reflex may play a role as well. Improvement of prosthodontics may not be sufficient to compensate for the maxillary resorption, additional procedures, such as insertion of endosseous implants to support the prosthetic construction, are needed. However, reliable insertion of implants is often complicated in the upper jaw because of insufficient height and width of the alveolar process. In such cases the insufficient bone volume of the maxilla has to be overcome by reconstructive pre-prosthetic surgery before implants can be installed at the preferred sites (Chanevaz 1990; Raghoobar et al. 1993, 1997, 1999, 2001; Van den Bergh et al. 1998, 2000; Ten Bruggenkate et al. 2000).

To establish an adequate environment for the insertion of endosseous implants, various grafting procedures have been developed to increase the bone volume. These procedures include bone onlays, Le Fort osteotomy with interpositional bone grafts and procedures to elevate the maxillary sinus floor with autogenous bone and/or bone substitutes (Smiler et al. 1987; Kent and Block 1989; Chanevaz 1990; Hochwald et al. 1992; Tidwell et al. 1992; Raghoobar et al. 1993, 1997; Cawood et al. 1994; Jensen et al. 1994; Lundgren et al. 1996; Hürzeler et al. 1996; Garg 1999). Based on good clinical results, sinus floor elevation procedures are commonly used in reconstructive pre-prosthetic surgery (Van den Bergh et al. 2000; Raghoobar et al. 2001). Notwithstanding the fact that elevation of the floor of the maxillary sinus has become a well-accepted pre-implantologic procedure, the effects of this procedure on maxillary sinus physiology are unknown. In particular, the impact of the partly filled up maxillary cavity after elevation on the covering membranous lining and clearance capacity of the sinus has not been extensively studied.

In this thesis the major effects of sinus floor elevation surgery on maxillary sinus physiology in humans are described.

Anatomic and physiologic aspects relevant to maxillary sinus floor elevation surgery

The maxillary sinuses are paired, approximately pyramid shaped, air-filled cavities surrounding the nasal vestibule. The function of the maxillary sinuses is still a matter of debate. The sinuses are thought to play a role in the shaping and weight reduction of the facial skeleton structure, phonetic resonance, air-conditioning, and olfaction (McGowan et al. 1993).

In its healthy state, the maxillary sinus has adequate clearance. To accomplish this, ventilation to the maxillary sinus is necessary (Drettner 1965; Aust et al. 1974a, 1974b). Via the ostio-meatal unit, ventilation and drainage of the sinus takes place. Clearance of the maxillary sinus is coordinated by ciliary movements of ciliated epithelial cells. In this way, the epithelial lining fluid, which is produced by goblet cells and seromucous glands of the antral mucosa, is transported towards the maxillary ostio-meatal unit. Via this, the lining fluid is drained into the nasal cavity, thus eliminating the inhaled small particles and/or micro-organisms. This mucociliary transport is an active transport system, depending on oxygen for its metabolism. The amount of oxygen absorbed from the blood is not sufficient to supply the oxygen consumption needed for proper ciliary activity. Additional oxygen has to be absorbed from the air within the sinus, thus stressing the need for adequate ventilation of the maxillary sinus (Drettner 1980).

The maxillary artery not only supplies the maxillary bone but also the maxillary sinus membrane (Schneiderian membrane). The posterior superior alveolar artery and the infra-orbital artery, both originating from the maxillary artery, have endosseous and extraosseous anastomoses and create a double arterial arcade around the maxillary sinus. The endosseous anastomosis mainly supplies the buccal side of the maxilla and the buccal part of the maxillary sinus membrane. The extraosseous anastomosis supplies the oral mucous membrane. The blood supply of the central and medial part of the maxillary sinus membrane is originating from the sphenopalatine artery, which is a terminal branch of the maxillary artery entering the maxillary sinus via the maxillary ostium (Kumlien et al. 1985). The endosseous and extraosseous arterial arcades, as well as the vessels of the maxillary sinus membrane are important for survival and incorporation of the inserted bone graft when performing a sinus floor elevation procedure (Solar et al. 1999). It should be mentioned that the vascularisation of the maxilla varies with age. With increasing age, the number of vessels in the upper jaw, as well as their diameter, decrease (Staudt et al. 1977). In case of severe resorption, the cortical bone in old

edentulous patients is too thin for containing blood vessels. In such patients, vascular supply of the maxilla (and the graft) is mainly provided by the periosteum, and thought to be limited (Traxler et al. 1999; Solar et al. 1999).

Regarding the venous and lymphatic drainage of the maxillary sinus, the main vascular plexus is located around the maxillary ostium. Inflammatory diseases of the nose might result in venous and lymphatic congestion and occlusion of the maxillary ostium, and development of mucosal swelling of the entire antral lining can be expected. Occlusion of the ostia may finally contribute to further sinus clearance impairment, stasis of fluid and consequently to development of sinusitis.

Sinus floor elevation surgery

Grafting of the sinus floor was introduced by Tatum in 1976, modified by Boyne and James in 1980, and remodified by Tatum in 1986. At present, the surgical technique as described by Tatum in 1986 is generally used. According to this technique access to the maxillary sinus is achieved by osteotomizing the lateral maxillary sinus wall. With a round burr, a small window is prepared in the lateral bony maxillary wall leaving the sinus membrane intact. Subsequently, the sinus membrane is carefully elevated and the mobilised part of the lateral sinus wall together with elevated sinus membrane is rotated medially and cranially. Bone grafts can be harvested from several donor sites. As an alternative bone substitutes or a mixture of autogenous bone and bone substitutes can be used. The most widely used donor site is the anterior iliac crest. The anterior iliac crest usually allows for harvesting plenty of cortical as well as cancellous bone to perform the elevation procedure. Usually one large monocortical bone block is harvested, followed by the harvesting of cancellous bone. In the cases in which very large volumes of bone are needed, the posterior iliac crest is a good alternative. The graft is shaped to fit the antral floor. Fixation is achieved by tight insertion of the shaped bone blocks into the previously created bony window. The remaining space is filled up with particulated cancellous bone (Figures 1A and 1B). Often, the alveolar process is of insufficient width. In such cases, cortical bone blocks can be shaped to widen the alveolar process as well and can be fixated with mini-screws. Again, particulated cancellous bone is used to fill up the remaining space surrounding the blocks. Watertight, but tensionless closure of the mucosal incisions is essential for smooth incorporation, because the graft can be compromised when exposed to the oral environment.

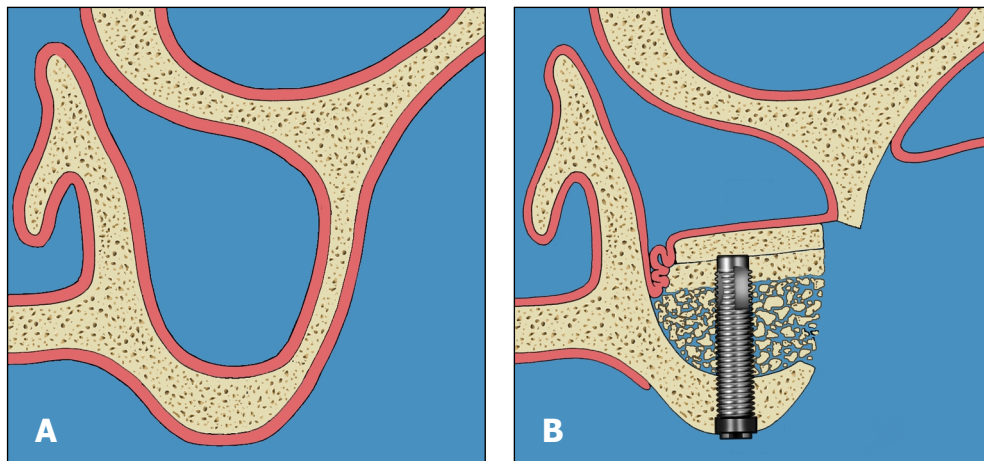


Figure 1 *Left maxillary sinus.*
A *Before sinus floor elevation surgery.*
B *Situation after sinus floor elevation surgery and implant insertion, before wound closure.*
The implant has been inserted in a one-step procedure.

Effects of elevation of the maxillary sinus floor on sinus physiology

Elevation of the maxillary sinus floor with autogenous bone grafts or alloplastic materials alters the anatomic relationship of the maxillary sinus and might be of influence on the function of the maxillary sinus.

Complications associated with maxillary sinus floor grafting are hematoma, accidental perforations of the sinus membrane, disturbed wound healing, wound dehiscence, wound infection, development of oro-antral communications, sequestration of graft material and sinusitis.

Sinusitis occurrence may be influenced by internal (e.g. diabetes mellitus) or external factors (e.g. discharge of grafting material due to accidental membranous perforations). Pre-existent sinus pathology and post surgery chronic maxillary sinusitis might compromise the success rate of the grafting procedure. The effects of pre-existing clearance disturbing factors on clearance of the maxillary sinus post elevation are not known yet. By contrast, many authors described the potential hazard of maxillary sinusitis post elevation (Misch 1987; Chanavaz 1990; Tidwell et al. 1992; Regev et al. 1995; Bhattacharyya 1999; Doud Galli et al. 2001). In these reports, the incidence of post-elevation maxillary sinusitis appeared to be up to

26%, (mean $13.8\% \pm 9.4\%$) but losing the inserted graft was reported in a few cases only. Looking at latter studies it has to be mentioned, however, that generally accepted ENT-criteria for diagnosing sinusitis and preoperative evaluation of sinus clearance related factors are lacking in these clinical reports on the development of post-elevation sinusitis (Yonkers 1992; Anon et al. 1997). For future studies the generally accepted ENT-criteria need to be an integral part of the study protocol as guided principle assessing post-elevation morbidity with emphasis on development of maxillary sinusitis.

With regard to the grafting material, postoperative maxillary sinusitis may compromise the survival and incorporation of the bone graft. In case of post-operative chronic sinusitis, not only the sinus membrane but also the graft and the surrounding maxillary wall can be involved in the inflammatory process. Consequently osteomyelitis might develop resulting in partial or total loss of the bone graft (Perloff et al. 2000). It is unclear whether insufficient graft circulation, e.g. due to overfilling of the sinus floor and/or to limited maxillary vascular supply in the old edentulous patient, might be considered an aggravating factor. With regard to the sinus membrane, surgical interventions in the maxillary sinus usually result in swelling of the epithelial lining (Stammberger 1986; Kennedy 1992). In particular when the post-operative mucosal swelling would develop around the maxillary ostium, the ostium might be occluded resulting in venous and lymphatic congestion. As a consequence any swelling of the sinus membrane will increase. Particularly vascular insufficiency might negatively affect the ciliary transport resulting in stasis of fluid in the sinus (McGowan et al. 1993), which in turn might further-compromise the survival of the inserted bone graft as well. These potential effects of sinus floor elevation surgery on the sinus membrane need further study.

With regard to the sinus flora, it has to be stated that even in a healthy state the maxillary sinus is not sterile (Hartog 1997). Reports on the effect of a sinus floor elevation procedure on the microbiological status of the maxillary sinus have not been available yet. This aspect needs further study, as e.g. the presence of old blood filling up the sinus together with a diminished patency of the ostium might result in a reduced colonisation defence and thus to the growth of (potential) pathogens.

Summarising, sinus floor elevation surgery might violate the anatomic integrity of the maxillary sinus and possibly interferes with physiologic mechanisms of the maxillary sinus.

Aim of the study

When considering the potential effects of elevation of the floor of the maxillary sinus with autogenous bone grafts mentioned above and the knowledge available in the literature, it appears that much is unknown about the effects of such a procedure on maxillary sinus performance. Therefore the aim of this study was to investigate the course, prevention and treatment of post-maxillary sinus elevation morbidity. Special attention is paid to the occurrence of maxillary sinusitis in a group of patients without pre-operative actual anamnestic, clinical and radiological signs of maxillary sinusitis.

The specific aims were:

- To evaluate retrospectively the long term clinical and radiographic outcomes and patient satisfaction after sinus floor elevation surgery with autogenous bone grafts (Chapter 2).
- To evaluate retrospectively the influence of sinus floor elevation surgery on the development of maxillary sinus pathology using generally accepted ENT criteria (Chapter 3).
- To evaluate the course of development of chronic maxillary sinusitis post-elevation. (Chapter 4).
- To evaluate prospectively the effects of sinus floor elevation surgery on the maxillary sinus physiology applying anamnestic and clinical investigations, radiodiagnostic evaluation and endoscopy (Chapters 5, 6).
- To assess prospectively the effects of sinus floor elevation surgery on the maxillary sinus performance by means of microbiologic and morphologic techniques (Chapter 6).
- To evaluate the diagnostic utility of conventional radiographic examination of Waters' projection of the maxillary sinus with particular regard to sinus mucosal swelling as a consistent sign of maxillary sinusitis (Chapter 7).

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