Maxillary Sinus Floor Elevation Surgery

Effects on Maxillary Sinus Performance
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Effects on Maxillary Sinus Performance

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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; Raghoebear 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; Raghoebear 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; Raghoebear 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 remodelled 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% ± 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).
References


Chapter 2

Maxillary Bone Grafting for Insertion of Endosseous Implants: Results after 12-124 Months

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Abstract

Insertion of endosseous implants in the atrophic maxilla is often complicated because of lack of supporting bone. Elevation of the floor of the maxillary sinus with autogenous bone graft has been proven to be a reliable treatment modality, at least in the short term. The long-term clinical and radiographic outcome with regard to the grafts, the implants and satisfaction of the patients with their implant-supported overdenture was studied in 99 patients. The sinus floor was elevated with bone grafts derived from the iliac crest (83 subjects, 162 sinuses, 353 implants), the mandibular symphysis (14, 18, 37), or the maxillary tuberosity (2, 2, 2). Before implant installation the width and height of the alveolar crest were increased in a first stage procedure in 74 patients, while in the other 25 patients elevation and implant installation could be performed simultaneously (width and height of the alveolar crest >5 mm). Perforation of the sinus membrane occurred in 47 cases, which did not predispose to the development of sinusitis. Loss of bone particles and sequestration were observed in one (diabetic) patient only, in whom a dehiscence of the oral mucosa occurred. A second elevation procedure was successful in this patient. Symptoms of transient sinusitis were observed in 3 patients. These symptoms were successfully treated with decongestants and antibiotics. Two other patients developed a purulent sinusitis which resolved after a nasal antrostomy. In all cases, the bone volume was sufficient for implant insertion. 32 of 392 inserted Bränemark implants (8.2%) were lost during the follow-up. After the healing period of the bone grafts, no sinus pathology was observed. The patients received implant-supported overdentures (72 patients) or fixed bridges (27 patients). Overall, the patients were very satisfied with the prosthetic construction. We conclude that bone grafting of the floor of the maxillary sinus floor with autogenous bone for the insertion of implants is a reliable treatment modality with good long-term results.
Introduction

Implant supported fixed and removable prostheses provide a proper treatment modality with reliable success, especially for the rehabilitation of an edentulous mandible (Adell et al. 1981; Engquist et al. 1988; Jemt et al. 1996; Batenburg et al. 1998). Prosthetic rehabilitation of the edentulous maxilla using endosteal implants often is limited by insufficient quality and quantity of available bone. Several grafting procedures have been described to create sufficient volume of bone for placement of implants in atrophic maxillae, including total or segmental bone onlays, Le Fort I osteotomy with interpositional bone grafts, and grafting of the maxillary sinus with autogenous bone or bone substitutes (Keller 1994; Cawood et al. 1994; van Steenberghe et al. 1997).

Bone onlays and Le Fort I osteotomies with interpositional grafts are the treatments of choice in cases with horizontal maxillary deficiency or with a wide interarch distance, but both procedures are contraindicated in patients with a normal or reduced interarch distance. By contrast, coronal displacement of the maxillary sinus floor by elevation of the inferior bone tissue increases the volume of bone for placement of implants without reducing the interarch distance. It is usually achieved by a modified Caldwell-Luc procedure in which the lateral wall of the maxillary sinus is fractured upward and the sinus membrane is raised (Boyne and James 1980; Tatum 1986). This procedure is particularly applicable for normal or reduced interarch distance, and it can be easily combined with procedures to enlarge the width of the alveolar crest. Several recent clinical studies and reports have attempted to evaluate the maxillary sinus elevation procedure using a variety of bone grafting materials such as autogenous bone grafts from the iliac crest and the oral cavity, as well as bone substitutes (Chanavaz, 1990; Hirsch and Ericson 1991; Tidwell et al. 1992; Williamson, 1996; Hürzeler et al. 1996; Wheeler et al. 1996; Lundgren et al. 1997; Block and Kent 1997; Watzek et al. 1998; Blomqvist et al. 1998; Kaptein et al. 1998a; Van den Bergh et al. 1998). In most retrospective studies, a variety of grafting materials and/or techniques have been used within the same study, without clearly specifying the criteria used for a particular grafting material in a particular patient. This makes retrospective analysis in those studies rather troublesome as to which extent a problem that occurs can be related to a particular grafting technique and/or grafting material.

The aim of this study was to evaluate the long-term clinical and radiographic outcomes as well as patient satisfaction after sinus floor elevation surgery with autogenous bone grafts.
Materials and Methods

Patients

Between 1988 and 1997, elevation of the maxillary sinus floor with autogenous bone grafts, often in combination with enlargement of the width of superior alveolar crest, was performed in 105 patients. Surgery and prosthodontics were performed within the same clinic. 6 patients had to be excluded from the study because they deceased (2 patients) or had moved abroad (4 patients) without leaving a change of address. The other 99 patients (58 women, 41 men; mean age 48±12 years, range 17-73 years at time of surgery) all agreed to participate in the study. The mean follow-up after implantation was 58±27 months (range 12 to 124

![Figure 1](image)

*Figure 1*
Frequency distribution of the patients (A) and implants (B) as a function of time.
months, median 60 months, Figure 1). The maxilla was edentulous in 75 patients, and partially dentulous in 24 patients. In the mandible the edentulous patients wore implant-supported overdentures (n=21) or full dentures (n=53). 25 patients were partially dentulous in the mandible.

Planning of treatment

Orthopantomograms, lateral cephalograms, and postero-anterior oblique radiographs were made to assess the height of the maxillary alveolar bone, the dimensions of the maxillary sinus, and the antero-posterior relationship of the maxilla to the mandible. The radiographs were also screened for sinus pathology. For every sinus to be included in this study, the alveolar height was measured on the orthopantomogram. The mean vertical height of the alveolar bone between the most caudal part of the maxillary sinus and the oral cavity was on average 3±2 mm, range 1-7 mm.

A diagnostic set up of each prosthesis was made and converted to a surgical template. Based on this it was decided whether an implant-supported overdenture or a fixed bridge had to be made for the edentulous patients. Deciding factors included aesthetics (support for lips and cheeks), estimated position of implants, intermaxillary relationship, parafunctions (for example bruxism) and the space available for the superstructure. A minimum of 6 implants with a length of at least 10 mm was installed in the edentulous maxilla. The implants were preferably equally distributed across both sides of the maxilla and connected with a superstructure. Prosthodontic considerations for additional insertion of implants in the anterior region included the need to position the implants as near as possible to the planned maxillary dental arch, sufficient intermaxillary space for the mesostructure and the overstructure, especially considering the distance to the occlusal plane, and the width of the prosthesis in the anterior region. In case the interarch distance was insufficient for prosthetic construction with an optimal aesthetic and phonetic result, 2 superstructures were planned supported by 3 implants, inserted in the region between the canine and first molar. Partially dentulous patients were all supplied with implant-supported fixed bridges.

Surgery

When iliac crest bone grafts were used, the patients were treated under general anesthesia; in all other cases surgery was performed under local anesthesia. Large autogenous cancellous bone grafts (n=83) were harvested from the superior anterior medial part of the iliac crest. When smaller amounts of bone were sufficient
for grafting, they were taken from the mandibular symphyseal area (n=14) or the maxillary tuberosity (n=2).

A two-stage procedure (first stage, bone grafting; second stage, placement of implants) was performed when the height of the maxillary bone and/or the width of the alveolar crest were less than 5 mm (74 patients, 137 sinuses, 306 implants). Otherwise, a one stage procedure (bone grafting and placement of implants) in the same session was performed (25 patients, 45 sinuses, 86 implants).

**Sinus floor elevation surgery with iliac crest bone grafts**

After harvesting the bone grafts, the maxillary surgical sites were infiltrated with a local anaesthetic containing epinephrine as a vasoconstrictor. The palatal mucosa was incised, just below and parallel to the top of the alveolar crest. After vertical releasing incisions had been made in the buccal mucosa, a mucoperiosteal flap was raised to expose the alveolar process and lateral wall of the maxilla. If necessary, the mobility of the reflected flap was enlarged by cutting the periosteam at the base of the buccal flap. The lateral wall of the maxillary sinus was fenestrated with a round bur at high speed and adequately cooled with sterile saline. Care was taken to preserve the mucosal lining. Subsequently, the sinus membrane was raised and the mobilized part of the lateral sinus wall, together with the raised sinus membrane, was rotated medially and upwards. Perforations of the sinus membrane were not treated as these defects were closed off by folding of the lifted membrane. No membranes were used to cover the lateral wall defect after the bone graft was placed. After grafting, the height of the maxillary bone had to be at least 13 mm.

In case of a one-stage procedure, the holes for the implants were drilled in the desired positions. Septa encountered in the sinus floor were removed to facilitate placement of the bone graft, which was then shaped to fit exactly into the maxillary sinus. A thin monocortical block of iliac bone was placed in the sinus with the cortical layer upwards and often another thin bone block was placed perpendicularly to increase stability. Great care was taken to secure initial stability of the grafts. The remaining space between the iliac bone block and the alveolar crest was filled with particulate cancellous bone. To enable insertion of an implant the graft was stabilized with a small clamp. Titanium implants (Brånemark®, Nobel Biocare, Göteborg, Sweden) were inserted through the alveolar bone into the grafts, using the surgical template. Up to 3 implants were placed in each bone graft. Both the implants and the grafts were additionally stabilized by anchoring of
the implants in the cortical bone block. Finally the wound was closed with horizontal mattress sutures.

Before harvesting bone grafts, the patients received broad-spectrum antibiotics, starting one hour preoperatively (intravenously) and continued orally for seven days after surgery. Postoperatively the patients received a 0.2% chlorhexidine mouth rinse (1 minute, 5 times daily) for 2 weeks. One month postoperatively, the edentulous patients were allowed to wear dentures if possible, after relining them in the operated areas and relining them with a soft liner. In the partially edentulous cases, in general no temporary prosthesis was made.

In case of the two-stage procedure the width of the alveolar crest also was reconstructed in 64 patients. After the sinus lift procedure, the width was increased by placing monocortico-cancellous bone blocks buccally of the cortex of the alveolar defect, with the cancellous side of the bone graft in contact with the jaw bone. The graft was fixed with titanium screws to the alveolar bone. Cancellous bone particles were used to fill the small gaps between the bone graft and the alveolar crest. The mean width of the alveolar crest after grafting was 7 mm (range 6.5 to 8). The antibiotics and oral hygiene regimen were the same as those used for the one-stage procedure. After a healing period of at least 3 months the implants were inserted using a surgical template. In 59 patients the bone volume was sufficient at the time of implantation, but in 5 patients (7 implants) the bone width was not enough. In these cases, the implants could be inserted with sufficient primary stability, although some treads of the implants were exposed. These threads were covered with bone and a GTAM® membrane (W.L. Gore and Associates, Inc, Arizona, USA).

6 months after insertion the implants were uncovered, the oral mucosa was thinned where applicable and the abutments connected.

**Sinus floor elevation surgery with intra-oral grafts**

In case of mandibular symphyseal or maxillary tuberosity bone grafts, the sinus-floor-elevation procedure was similar to the procedure for iliac crest grafts. Mandibular symphyseal bone grafts provided less cancellous bone, and in the case of maxillary tuberosity bone grafts less cortical bone was available.

**Implants in the anterior maxilla**

In addition to the insertion of implants in the grafted maxillary sinuses, 160 Bränemark implants were inserted in the anterior region in pre-existing maxillary bone. For proper positioning of these implants, the same surgical template was
used. In 7 patients (10 implants) in which the one stage procedure was used, some threads of the surface of the implant were exposed. The exposed surfaces were covered with bone and a GTAM® membrane (W.L. Gore and Associates, Inc, Arizona, USA).

Prosthodontics

The patients were rehabilitated with implant-supported overdentures (n=72), full bridge (n=3) or partial bridge (n=24).

Experimental setup

All patients were on a recall schedule at least once a year. Complications during surgery and postoperative healing (inflammation, wound dehiscence, sequestration, loss of bone particles and sinusitis) and loss of implants were obtained from the patients' records. In addition to this standard recall schedule, all patients were recalled for a clinical and radiographic examination between September 1997 and March 1998. During this recall visit the mesostructures were removed and all implants were individually checked if they were mobile. The clinical examination included assessment of peri-implant soft tissue, bleeding index (Mombelli et al. 1987; Mombelli and Lang 1992), gingiva index (Silness and Löe 1964) and the probing depth (Merrit-B, Hu-Friedy, USA). Sensory changes of the skin were examined by stroking the upper lip and cheek with a cotton pellet and by pinching the lower lip in a pair of tweezers. Also plaque index (Mombelli et al. 1987; Mombelli and Lang 1992) and presence of calculus was registered.

Radiological evaluation to detect marginal peri-implant bone loss was carried out by 2 observers using orthopantomograms and intra-oral dental radiographs taken immediately after the prosthetic procedure and at yearly intervals. Peri-implant bone loss was rated on a 4-point scale: 0 = no apparent bone loss; 1 = reduction of the bone level not exceeding one third of the length of the implant; 2 = reduction of the bone level exceeding one third but not one half of the length of the implant; and 3 = reduction of the bone level exceeding one half of the length of the implant.

Sinusitis was suspected to be present if the patient complained about pain or tenderness in the region of the maxillary sinus, nasal obstruction and mucopurulent rhinorrhea. The clinical diagnosis of sinusitis had to be confirmed by rhinoscopy (i.e. hyperaemic inflamed nasal mucosa with mucopurulent secretion) and inspection of the oropharynx to detect post nasal drip. In addition, Waters’ radio-
graphs were taken and compared with presurgical X-rays to detect the presence of new sinus pathology.

Implant failure was defined according to the following criteria: implant mobility; persistent pain, infection, presence of peri-implant radiolucency; significant, ongoing cervical or apical implant-related bone loss (exceeding one third of the length of the implant); or the implant could not be used for the prosthetic rehabilitation.

Patient satisfaction was assessed by using a validated questionnaire (Vervoorn et al. 1988). The questionnaire focused on satisfaction with function of the prosthetic construction (overdenture and fixed bridge) and with aesthetics. 8 items were presented with a five-point rating scale on which the patient indicated to what extent he or she was (dis)satisfied (1 = very satisfied, 2 = satisfied, 3 = neither satisfied nor dissatisfied, 4 = dissatisfied, 5 very dissatisfied). The patient’s overall treatment satisfaction was expressed on a 10-point rating scale (1 = very bad to 10 = excellent).

Statistics
The 95% confidence interval (CI) of differences between ‘survival-rates’ were calculated; a difference was considered statistically significant on a 5% level when this confidence interval did not contain 0.

Results
Surgical complications
Although the sinus membrane was perforated during surgery in 47 cases (26%), healing was uneventful, and loss of bone particles through the nose was not observed. Symptoms of transient sinusitis were observed in 3 patients, which resolved with decongestants and antibiotics used for a period of 2 weeks. These patients had a history of sinus maxillary clearance related problems (symptoms of chronic maxillary sinusitis) preoperatively, and in one of them the sinus membrane had been perforated. Development of purulent sinusitis was observed in 2 patients without predisposition for sinusitis. In one of them, the sinus membrane had been perforated accidentally during surgery. In both patients the purulent sinusitis healed uneventfully after nasal antrostomy of the middle meatus.

2 patients developed a fistula near the GTAM® membrane. Both membranes were removed. At the abutment connection a dehiscence of 2 treads of the im-
plant was noted in 1 of these patients. In all other patients the implants were covered with bone-like-tissue.

In 4 patients, a wound dehiscence occurred near a screw used to fix the bone graft for the widening of the alveolar crest. Healing was uneventful after removal of that screw. Incision breakdown occurred in the first week after bone grafting in 7 patients. In 6 of them the dehiscence closed spontaneously after 2 weeks, while in the other (diabetic) patient loss of bone particles and sequesters was observed. The bone sequesters were removed and the wound was closed with the buccal fat pad. Wound healing was uneventful, but the volume of the remaining bone was insufficient for insertion of implants. In this case a second elevation procedure was performed, where after 8 implants could be inserted successfully.

No major complications were observed at the donor sites. 1 patient had a wound haematoma and 2 patients had a seroma that had to be evacuated surgically. In all other cases postoperative healing was uneventful, although the majority of the patients suffered from pain, discomfort, and disturbances in gait. In most patients, the latter problems subsided within 4 weeks postoperatively, but 6 patients experienced hip-related discomfort up to 3 months post-surgery. In the intra-oral bone harvesting areas, no damage to teeth or roots was observed. Transient hypoesthesia of the labial gingiva of the donor site (mandibular symphyseal bone graft) was observed in 1 patient.

Healing results

A total of 392 Brånemark implants (13 mm: n=79; 15 mm: n=304; 18 mm: n=9) were placed in 182 grafted floors of maxillary sinuses, viz. 353 implants in iliac crest grafts (162 sinuses), 37 implants in symphyseal bone grafts (18 sinuses), and two implants in a bone graft taken from the maxillary tuberosity (2 sinuses). Up to the time of the last recall visit, 32 out of 392 implants (survival rate 91.8%) had to be removed in 18 patients: 7 one-stage implants (survival rate 91.9%) and 25 two-stage implants (survival rate 91.8%). There were no significant differences in survival rate between implants inserted as a one-stage or a two-stage procedure (p>0.05). 18 implants in 13 patients were lost during the first 6 months. 9 implants were lost 6-30 months after loading and 5 implants (1 patient) were mobile at the time of the study, 2 of these 5 implants showing pus in the implant sulcus. The latter patient experienced also a slight hyposensibility of the left side of the upper lip. In the group of 75 edentulous patients (149 sinuses, 326 implants), 30 implants were lost (survival rate 90.8%), while in the group of 24 partially edentulous patients (33 sinuses, 66 implants), 2 implants were lost (survival rate 97.0%, p<0.05).
30 of the 32 lost implants had been inserted in iliac crest bone grafts (survival rate 92.5%), and the other 2 in symphyseal bone grafts (survival rate 94.6%). There was no significant difference in survival rates with regard to whether bone graft was harvested from the iliac crest or from the mandibular symphysis (p>0.005).

23 of the 32 lost implants had to be replaced with new implants. In 2 patients, in whom in total 8 implants had been lost, there was not enough bone for insertion of implants necessitating a second elevation procedure (iliac crest: 1 patient and symphysis: 1 patient). There was no need to replace the remaining lost implants (n=9), as proper prosthodontic rehabilitation could be undertaken without replacement.

Of the 160 implants inserted in non-grafted sites of the anterior maxilla, 12 implants failed (survival rate 92.5%). 7 implants were lost during the healing phase (up to 6 months), 3 implants after loading for 6-30 months and 2 implants could not be used for prosthetic construction, because the position was not optimal.

The parameters for evaluating peri-implant tissue health showed favorable results (Table 1). Only 2 patients with overdentures needed correction of the peri-implant mucosal hyperplasia during the follow-up.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Mean values and standard deviations (SD) of plaque-index, gingiva-index, bleeding-index, calculus index and probing depth.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaque-index (score 0-3)</td>
<td>0.7 ± 0.8</td>
</tr>
<tr>
<td>Gingiva-index (score 0-3)</td>
<td>0.4 ± 0.8</td>
</tr>
<tr>
<td>Bleeding-index (score 0-3)</td>
<td>0.8 ± 0.9</td>
</tr>
<tr>
<td>Calculus-index (score 0-1)</td>
<td>0.3 ± 0.4</td>
</tr>
<tr>
<td>Probing depth in mm</td>
<td>4.2 ± 1.5</td>
</tr>
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</table>

Radiology, at time of evaluation indicated no loss of marginal bone around 463 implants and slight bone loss of the marginal alveolar crest not exceeding 1/3 of the implant length around 41 implants of which 28 in the posterior region. Bone loss between 1/3 and 1/2 of the implant length was seen around 4 implants, all in the posterior region. In 1 patient, the bone loss progressed after the first year post-implantation. In that patient the iliac crest bone graft resorption resulted in the loss of 5 implants in the posterior region (bone loss exceeding 1/2 of the implant). Latter 5 implants were mobile at time of investigation. No further bone loss was observed in all other cases after one year post-implantation. According to the fail-
ure criteria applied in the present study, the success rate was 90.8% (36/392 implants) in the posterior region and 92.5% (12/160 implants) in the anterior region.

The mean score on the questionnaire concerning denture satisfaction was 2.05 ± 0.9. The mean satisfaction score with regard to the total treatment was 7.6 ± 1.2.

**Discussion**

The procedure described to increase the bone volume in the atrophic maxillae of edentulous and partially dentulous patients with autogenous bone grafts has proven to result in prosthodontic success in a group of patients with insufficient volume of bone in the posterior maxilla for reliable placement of implants. The overall success rate of implants in this retrospective study was 90.8% for implants placed in the posterior region and 92.5% for implants additionally inserted in the anterior region.

In this study a significant difference in implant survival rate between the partially dentulous (97.0%) and edentulous maxilla (90.8%) was observed, which is in agreement with the study of Esposito et al. (1998a). A possible explanation is that partially edentulous patients have less resorbed jaws (speaking in favor of sufficient bone volume and bone quality). In addition, in contrast to partially dentulous patients, edentulous patients were allowed to wear their upper dentures (relieved in the operated areas) during the healing phase. Moreover, in partially dentulous patients, occlusal forces on the prosthetic construction are merely transferred to the natural dentition. Since the overload is directly proportional to the bone-implant contact, early loss of the implants can occur when wearing prostheses during the healing phase which may be related to loss of implants. In the edentulous patients there is thus an increased risk of implant failure due to biomechanical imbalance and poor bone quality. Most likely, late failures have a multifactorial background, such as overload and bacterial infection (Esposito et al. 1998b). In most articles, the results of implant survival in the partial dentulous and edentulous maxilla were not analyzed separately, but there are some indications that the survival rate is higher in case of partially dentulous patients (Mazor et al. 1999).

The question of timing, i.e. whether to insert implants simultaneously with the elevation procedure or as a delayed procedure, remains unresolved. In this study no significant difference in implant survival of the simultaneous and delayed inserted implants was noted. Proponents of delayed placement favor creation of a
solid foundation prior to implant placement. This may improve site selection and also takes advance of bone healing biology (Moy et al. 1993; Blomqvist et al. 1998). Proponents of simultaneous placement favor one-stage surgery as being less invasive, more cost-effective, and more time-efficient. From a biologic point of view, a two-stage surgery is preferable, because time will be allowed for revascularization and incorporation of the grafted bone before the implants are inserted. If the residual bone height beneath the maxillary sinus is at least 5 mm, the results of a one-stage procedure (simultaneous grafting and insertion of implants) appear to be equivalent to those of a two-stage procedure, since initial stability of the implants can be achieved by both approaches. Thus, the most important issues to be addressed are initial stability and optimal positioning of the implants. If insufficient bone remains to provide proper implant stability and positioning, delayed implant placement is the treatment of choice (Block and Kent 1997).

Perforation of the sinus membrane was the most common complication during the sinus floor elevation procedure. The occurrence of perforations was not related to increased loss of implants. This is in accordance with the literature (Jensen et al. 1994; Timmenga et al. 1997). An advantage of the cortical bone plate on the top of the graft just below the sinus membrane is that this bone plate will prevent shedding of bone particles into the maxillary sinus in case a perforation was not closed off by folding of the membrane (Raghoebhar et al. 1997). Shedding of bone might lead to local inflammation and subsequently increase resorption of the bone graft. A second advantage of a bone graft with a cortical bone plate is that the bone graft is fixed when the implants are inserted simultaneously, which provides optimal stability for both the bone grafts and implants. A third advantage is that the bone particles can be firmly packed into the created space. Incision breakdown is rare but may occur because of ischemia from a lack of blood supply coursing across the crestal tissue, especially if the incision was placed too far palatally to the alveolar crest (Block and Kent 1997).

In our study, 5 patients (5%) developed signs of sinusitis, while other authors have reported transient sinusitis to occur in 10-26% of their patients (Tidwell et al. 1992; Block and Kent 1997; Kaptein et al. 1998a). The sinus mucosa will usually regenerate across the immobilized bone graft during normal healing. It has been reported that large sinus membrane perforations should be repaired with collagen (Block and Kent, 1998) or fibrin adhesive (Sullivan et al. 1997). Suturing is very difficult and sometimes causes even greater perforations. In 1 of the 2 patients who developed purulent sinusitis, a perforation of the sinus membrane of 5 mm had occurred during the elevation procedure. Inflammation of this sinus possibly
might have been related to shedding of bone. In the patient without a perforation of the sinus membrane, development of purulent sinusitis was probably due to the combination of hematoma and a temporarily disturbed sinus clearance.

Various space maintainers have been proposed, but from both a clinical and biological point of view filling the bony defect with autogenous bone is preferred to filling of the defect with allogeneic materials like hydroxyapatite, demineralised freeze dried bone or a combination of both. There is still lack of sound scientific data supporting the use of these heterogeneous bone-filling materials. Autogenous bone grafts possess excellent space maintaining properties because they support membranes and act as an osteoconductive scaffold during osteoblast bone formation (Buser et al. 1992). This together with the high concentration of osteocompetent cells within these grafts explain why we prefer autogenous bone grafts for elevation of the maxillary sinus floor. Support for this view comes from a histomorphometric study on bone formation within grafted sites (Moy et al. 1993). These authors showed that the yield of bone after grafting with cortical chin bone was 59.4%, while the yield after grafting with either hydroxyapatite graft alone, hydroxyapatite mixed with cortical bone, and hydroxyapatite mixed with demineralised bone was 20.3%, 44.4%, and 4.6%, respectively. These results indicate that the amount of bone formed within the sinus is the highest for autogenous bone grafts.

The use of mandibular bone grafts for the elevation of the floor of the maxillary sinus is growing (Hirsch and Ericsson 1991). Resorption of these bone grafts after transplantation is less when compared with iliac crest, tibial, or rib grafts. Other advantages of intra-orally harvested bone grafts are the use of local anesthesia instead of general anesthesia, a relatively short operating time, no need for postoperative hospitalization, less morbidity at the donor sites, and lower costs (Hirsch and Ericsson 1991; Jensen et al. 1994; Raghoebear et al. 1996; Williamson et al. 1996). A disadvantage is that the intra-oral donor sites offer smaller volumes of bone than the iliac crest. In general, rather large amounts of bone are needed to establish adequate elevation of the maxillary sinus floor, particularly in bilateral edentulous patients or in combination with a reconstruction of the width of the alveolar crest. We had to use iliac crest grafts in most of our cases, because of the volume of bone required to be grafted. There was no difference in implant survival when comparing iliac crest bone with chin bone. The easy availability of chin grafts should be considered as an advantage. However, as reported the morbidity of harvesting bone from the anterior superior medial aspect of the iliac crest is low
(Kalk et al. 1996; Williamson et al. 1996). No serious complications were encountered in the present study as well.
Overall, the patients were satisfied with their prosthetic construction. The patient’s satisfaction index in the present study with regard to the total treatment (Kaptein et al. 1998b) appears to be comparable to the index of their study although a different scale is used.

From this study we conclude that sinus floor elevation surgery with autogenous bone grafts is a reliable procedure if properly planned and performed. It has been shown to result in good overall denture satisfaction of patients. The procedure is not without complications and the surgeon must be able to manage problems that arise peroperatively as well as those that develop in the early and late postoperative phases.

References


Chapter 3

Maxillary Sinus Function
after
Sinus Floor Elevation Surgery

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Abstract

The influence of maxillary sinus floor elevation surgery for the insertion of dental implants on the function of the maxillary sinus has not been well investigated. In this study the influence of sinus floor elevation surgery on the development of maxillary sinus pathology was evaluated using generally accepted diagnostic criteria.

A group of 45 patients, in whom a sinus floor elevation surgery procedure had been performed, was evaluated for sinus pathology, 12 to 60 months after bone transplantation and implant insertion, using a questionnaire, conventional radiographic examination and nasendoscopy.

Postoperative maxillary sinusitis was detected in two of five patients with a predisposition for sinusitis but in none of the other 40 patients. The occurrence if iatrogenic sinus membrane perforations during surgery was not related to the development of postoperative sinusitis in patients with healthy sinuses.

The occurrence of postoperative chronic sinusitis appeared to be limited to patients with a predisposition for this condition. These predisposing factors need to be considered when evaluating patients for sinus floor elevation surgery procedures.
Introduction

In patients with an extensive resorption of the maxillary alveolar ridge and functional denture problems, elevation of the maxillary sinus floor with bone grafts makes a reliable insertion of endosseous implants possible for the support of an upper full denture. Different surgical procedures using a variety of grafting materials have been reported in literature (Boyne and James 1980; Branemark et al. 1984; Tatum 1986; Misch 1987; Smiler et al. 1987; Wood and Moore 1988; Kent and Block 1989; Chanavaz 1990; Hirsch and Ericsson 1991; Jensen et al. 1990 and 1991; Hall and McKenna 1991; Hochwald et al. 1992; Smiler et al. 1992; Tidwell et al. 1992; Raghoebbar et al. 1993; Small et al. 1993; Jensen et al. 1994; Keller et al. 1994). Elevation of the maxillary sinus floor usually is performed through an osteotomy of the lateral maxillary sinus wall, careful evaluation of the sinus membrane, and medial and upward rotation of the elevated sinus membrane together with the mobilized bony part of the lateral sinus wall (Boyne and James 1980; Tatum 1986; Raghoebbar et al. 1993). Thereafter, the space created in the sinus is firmly packed with autogenous bone and (or) bone substitutes. According to the literature, the incidence of development of maxillary sinusitis following an elevation of the sinus floor ranges from 0-26% of the cases (Misch 1987; Quiney et al. 1990; Chanavaz 1990; Tidwell et al. 1992; Ueda and Kaneda 1992; Kent and Block 1993; Jensen et al. 1994). This percentage is lower than one would expect on theoretical grounds. Because postoperative sinusitis could possibly compromises the success of the sinus graft or implants and the patient’s physical well-being in general, appropriate preoperative screening for disturbed drainage of the sinus seems mandatory.

Altered anatomic relations in the nasal cavity and the area of the ostio-meatal complex are often involved in sinus clearance disturbances. Diminished maxillary sinus clearance is closely related to a reduced passage of the maxillary ostium (Myerson 1932; Aust and Drettner 1971, 1974 and 1978; Drettner 1975; Aust et al. 1976; Daele and Melon 1976; Bertrand and Robillard 1985; Scharf et al. 1995). Several studies on the function of this ostium have shown a reduced size in case of sinusitis (Carenfelt and Lundberg 1977 and 1987; Wigand 1981; Ferguson et al. 1988; Stierna et al. 1991). Relevant drainage-related factors include septum-deviation, nasal polyposis, allergy, obstructive lung diseases, infundibular pathology and radiation therapy. Another potential drainage-related factor might be a perforation of the membranous lining of the maxillary sinus during the sinus lift operation (Kent and Block 1993; Jensen et al. 1994). There is also a suggestion,
that maxillary sinus floor elevation contributes to the development of sinus cysts (Misch et al. 1991). The aim of this study was to evaluate the influence of the sinus floor elevation surgery procedure on the development of maxillary sinus pathology.

Patients and Methods

Patients

Between 1990 and 1994, 45 patients (22 women and 23 men; mean age 44 years, range 18-65 years) with insufficient bone height in the posterior part of the maxilla for the insertion of endosseous implants were treated with elevation of the floor of the maxillary sinus with autogenous bone grafts according to the protocol of Raghoebear et al. 1993. Preceding the surgical procedure, all patients were asked about their history of maxillary sinusitis-related symptoms. A questionnaire on sinus-related factors had to be completed and a radiographic examination (Waters’ view) was performed. Perforation of the sinus membrane during the elevation procedure was noted. All patients received antibiotics (1 g Cephalosporine started 1 hour preoperatively, 3 times a day, and continued for 1 week). Postoperatively all patients were seen at regular intervals and asked specifically about sinus problems. Complications of the surgical procedure, including infection of the maxillary sinus, loss of bone particles through the nose and wound dehiscence also were recorded. After abutment insertion (6 months after implantation), all patients were supplied with implant-supported upper dentures or fixed bridges.

Criteria for diagnosing maxillary sinusitis

Sinusitis is characterized by a typical triad of symptoms: nasal congestion or obstruction, pathologic secretion and headache (Yonkers 1992). However, these symptoms are extremely variable. Sinusitis is suspected in patients complaining of pain or tenderness in the region of the sinus, in combination with mucopurulent rhinorrhea.

To diagnose sinusitis, examination of the condition of the nasal mucosa is mandatory. Mucosal redness and edema, and the presence of mucopurulent discharge around the ostium, are the most important clinical criteria for confirming the diagnosis sinusitis.

Although computer tomography (CT)-scanning of the paranasal sinuses gives more details, mucosal thickening, an air-fluid level or opacifications are diagnosed
reliably with conventional radiographic examination. In case of protracted symptoms of sinusitis, additional procedures especially for the evaluation of the drainage from the sinus and sinuscopy, are indicated.

Evaluation

To assess for any sinus pathology caused by the sinus floor elevation procedure, the patients were recalled for a clinical and radiographical examination 12 to 60 months after grafting. The assessments included the following parameters:

- Presence of actual sinus pathology on conventional radiographs (Waters’ view), comparison with presurgical radiographs.
- Evaluating for any sinus pathology related to surgery, including perforation of the sinus membrane during the operation, infection of the maxillary sinus postoperatively, loss of bone particles through the nose and wound dehiscence.
- Nasendoscopic examination. Following local anaesthesia and decongestion of the nasal mucosa, inspection of the middle meatus was performed to gather information about the drainage of the maxillary sinus and ethmoids in the infundibular region. A rigid Hopkins fiberoptic scope with a diameter of 4 mm and an angle of vision of 30° was used.

Statistical analysis

A $\chi^2$ test was performed to assess for any significant difference in the occurrence of postoperative sinusitis between the group of patients preoperatively suffering from (transient) sinusitis and patient without such symptoms.

Results

Preoperatively, two patients had a proven allergy to the housedust mite, and three patients had obstructive lung disease (predisposing factors for sinus pathology). These patients had recurrent periods of sinusitis for many years. At the time of the operation, however, these patients showed no clinical and radiographical signs of any sinus disorder. The other 40 patients showed neither clinical nor radiographic signs of any sinus pathology preoperatively.

A total of 85 sinus floors were grafted. In 29 of these sinuses (34%), the sinus membrane had been perforated accidentally during the operation. Neither wound
dehiscence nor loss of bone particles through the nose had occurred in any of the patients during the recall periods. One patient mentioned a change in the sound of the voice as a result of the grafting procedure.

Two weeks post-operatively, two of the five patients with a predisposition for sinusitis developed a subacute maxillary sinusitis, which was confirmed clinically and radiographically (Figure 1). In one of these patients, the sinus membrane had been perforated accidentally during the surgical procedure. In both patients, the sinusitis symptoms ceased after treatment with antibiotics and decongestants. In none of the other 40 patients was an episode of sinusitis recorded, although the sinus membrane had been perforated accidentally in 28 patients.

Sinusitis as a complication of a sinus floor elevation surgery procedure has a significantly higher incidence in patients with predisposing factors for maxillary sinusitis ($\chi^2 = 8.95$, df = 1, $p < 0.01$), than in patients with predisposition for sinusitis.

Endoscopic assessment of the nasal cavity showed oversized turbinates and septal deviation combined with a nasal spine in the 5 previously mentioned at-risk patients. Visualisation of the maxillary ostium in the middle meatus showed evidence neither of preexisting (subclinical) maxillary sinusitis, nor of other pathology in the 40 asymptomatic patients.

**Figure 1** X-Rays showing maxillary sinusitis after sinus floor elevation surgery.
Discussion

The results of this study show that the incidence of maxillary sinusitis after bone grafting of the sinus floor is low. In patients without preexisting sinus problems, no acute symptoms were included by this procedure nor did symptoms develop during the 12-60-months follow-up period. Transient sinusitis only developed in patients with a predisposition for sinusitis, but even in these patients the symptoms ceased after appropriate treatment, and did not reoccur. Thus, sinus drainage did not seem to be compromised in healthy persons after sinus floor elevation surgery, nor did accidental perforations of the mucous lining of the maxillary sinus result in sinusitis postsurgically. These perforations need no special treatment. In addition, the cortical bone plate placed just below the sinus membrane prevents spill of the grafted material through an incidental mucosal perforation (Raghoebar et al. 1993).

Previous investigations reported acute sinusitis up to 26% after sinuslifting (Misch 1987; Chanevaz 1990; Quiney et al. 1990; Tidwell et al. 1992; Ueda and Kaneda 1992; Kent and Block 1993). However, an evaluation according for accepted criteria on diagnosis as well as preoperative evaluation of sinus drainage-related factors, is lacking in these clinical reports. It has been suggested that all patients should be evaluated intranasal preoperatively observation to determine the size of the inferior turbinate and the position of the nasal septum. When these structures are deviated in form and size and have caused chronic sinus problems, sinus floor grafting is contraindicated (Kent and Block 1993) before their correction. To select patients with an increased risk on the development of sinusitis we recommend that only patients suffering from previous symptoms of sinusitis or predisposing factors should be evaluated preoperatively to rule out structural drainage problems of the paranasal sinuses. In case of compromised sinus drainage, sinus floor elevation surgery procedures may reduce the sinus drainage and thus may provoke exacerbations of sinusitis.

Radiographic examination of the maxillary sinus may show mucosal pathology. However, it should be mentioned that the reliability of this information appeared to be 73% (Buitre 1976). Nasendoscopy has been shown to be a more detailed and reliable diagnostic method than conventional radiographic examination alone.

The considerable discrepancy between conventional radiographic examination and endoscopic findings, has made nasendoscopy widely accepted. Nasendoscopy provides an excellent view of the anatomic relations in the nasal cavity and
middle meatus. If preoperatively sinus clearance disturbing factors are observed, further investigations should be made. For instance, nasal obstruction, is often seen in patients with septum deviation or allergy, combined with oversized inferior and middle turbinates. Altered airflow may then induce irritation of the nasal mucosa. Increased thickness of the mucosal lining may reduce the passage of the maxillary ostium. Knowledge of the anatomic relations of the structures of the nasal cavity and the infundibulum are important for understanding pathogenetic mechanisms of maxillary sinusitis. However, in this study, nasendoscopy did not demonstrate additional cases of maxillary sinusitis, compared with only radiography. Nevertheless, when sinus drainage-disturbing factors are present, or when dealing with drainage-compromised patients, endoscopic examination is helpful in diagnosing (subclinical) sinusitis as a risk factor in patients undergoing the sinus floor elevation procedure. Preoperative evaluation of sinus drainage-related factors, and additional radiographic examination, will detect the presence of an asymptomatic maxillary sinusitis. In the literature however, there is a considerable discrepancy with regard to detection of maxillary sinusitis using conventional radiographic examination and endoscopy (Buiter 1976). It is true that since the introduction of nasendoscopy, visualisation of the osteo-meatal complex and nasal vestibulum plays an important role in the evaluation of sinus drainage-pathology, and the diagnosis of sinusitis.

It is prudent to evaluate all patients with a history of frequent sinusitis to rule out the presence of an obstructive phenomenon which could be aggravated by inflammation associated with the sinus grafting procedure. From this study it is concluded that elevation of the maxillary sinus floor by autogenous bone grafting in patients without sinus problems and no radiographic evidence of pathologic disease does not induce sinusitis. In these cases nasendoscopy is not necessary. A prospective study evaluating preoperative nasendoscopy before maxillary sinus floor elevation needs to be done recommending nasendoscopy for all patients who have a history of sinus clearance impairment factors.

References


Chapter 4

Maxillary Sinusitis after Maxillary Sinus Floor Elevation Surgery

a Report of 2 Cases

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Abstract

Maxillary sinusitis has been described as major complications of maxillary sinus floor elevation surgery. According to the literature, the incidence of maxillary sinusitis after maxillary sinus floor elevation surgery with iliac crest bone ranges from 0-26%. In our patient material, (n=156), development of chronic maxillary sinusitis was a rare condition. It was observed in two (1.5%) of the treated patients. These two cases are discussed.
Introduction

Sinus floor elevation surgery with an autogenous bone graft is a generally accepted pre-implantology procedure to enable successful placement of endosseous implants in an optimal prosthetic position. As reported in literature, complications of the sinus floor elevation procedure predominantly consists of disturbed wound healing, haematoma, sequestration of bone and (transient) maxillary sinusitis (Raghoobar et al. 1993, 1997). The last complication can occur as a result of contamination of the maxillary sinus with oral or nasal pathogens or because of a lack of asepsis during the surgical procedure (Misch 1992). Other causes are ostial obstruction due to postoperative swelling of the maxillary mucosa (Meyerson 1932; Drettner 1965; Aust and Drettner 1974), and nonvital bony fragments freely floating in the maxillary sinus (Perko 1972).

The incidence of maxillary sinusitis after sinus floor elevation surgery with iliac crest bone grafts ranges from 0-26% (Misch 1987; Chanavaz 1990; Quiney et al. 1990; Tidwell et al. 1992; Ueda and Kaneda 1992; Kent and Block 1993; Jensen et al. 1994; Regev et al. 1995; Kaptein et al. 1998). However, one has to consider that these data are derived from clinical studies in which presence of maxillary sinusitis was not scored according to standard criteria in the field of otolaryngology for the diagnosis of sinusitis (Buitser 1976; Kennedy 1985, 1992; Stammberger 1986; Schaefer et al. 1989; Davis et al. 1991; Lanza and Kennedy 1997; Hartog 1997), and specific preoperative evaluation of sinus drainage was not performed. Timmenga et al. (1997), reported that clearance of the maxillary sinus is rarely compromised after maxillary sinus floor elevation, and that the development of a chronic maxillary sinusitis, with all its therapeutic consequences, still has to be considered as a rare condition.

Between 1988 and 1998, 156 patients have been treated in our clinic; 7 patients (4%) developed a transient (subacute) sinusitis, while 2 patients (1.5%) developed a chronic maxillary sinusitis. In this paper these 2 complicated cases of chronic (purulent) maxillary sinusitis following sinus floor elevation with autogenous bone grafts are discussed and guidelines for specific treatment of both transient and chronic maxillary sinusitis are given.
Report of Cases

Case 1

A 56-year-old edentulous female was referred to our hospital because of lack of retention of her upper full denture as a result of extreme resorption of the maxilla. She complained of functional chewing problems, and lost 10 kilograms body weight during the last three years. At the time of referral she weighed 54 kg (height 168 cm). Severe resorption of the maxilla (Cawood Class VI) made it impossible to solve her denture-related problems with a conventional upper denture. Psychological screening indicated no contraindications for implant treatment.

The history and clinical and radiographic screening before sinus floor elevation surgery showed neither a history nor actual signs of sinus-related pathology. Therefore, nasendoscopy was not performed. Subsequently, the floor of the maxillary sinus was elevated and the width of the alveolar crest was increased bilaterally with an autogenous bone graft from the right iliac crest. Cephradine (i.v. 1 g, 3 times daily) was administered for 48 hours, starting one hour preoperatively. No complications occurred during the surgical procedure; the mucous lining of the maxillary sinus was not perforated. Wound healing was uneventful, however 3 weeks post-surgery, the patient developed maxillary sinusitis on the left side. The patient had pain in the left paranasal region, mucopurulent rhinorrhea and postnasal drip. Radiographic examination (Waters’ view) showed an opaque left maxillary sinus (Figure 1A). These complaints did not cease on conservative treatment, (amoxicillin-clavulanate 500/125 mg, 3 times daily), continued for two weeks, in combination with nasal decongestants (xylomethazoline 0.1%, 4 times daily), so it was decided to surgically improve sinus drainage.

Initially an inferior meatal antrostomy was made, and a silicone drain was left in the left maxillary sinus. Sinus irrigation was performed every second day and continued for two weeks. Pseudomonas species were found by microbiological examination of the maxillary sinus aspirate. Therefore antibiotic treatment was changed into ciprofloxacine 750 mg, 2 times daily, for two weeks. Because recovery did not occur, a computed tomography (CT)-scan was performed. The CT scan showed complete opacity of both the left maxillary and anterior ethmoid sinuses and a sequestrum in the left maxillary sinus (Figure 1B). Therefore, antrostomy in the middle meatus and endonasal ethmoidectomy were performed under general anaesthesia. During the operation the left maxillary sinus mucosa showed edematous hyperaemic polypoid changes with mucopurulent secretions. The sequestrum was removed. In spite of this maxillary sinus empyema, the re-
mainly grafted bone was still fixed and had appeared to be vital. Nasendoscopic treatment was carried out to prevent the development of mucosal adhesions. Successful recovery occurred within four weeks (Figures 1C, 1D).

Three months after bone grafting of the sinus floors, the bone volume seemed to be sufficient for insertion of 6 implants (Figure 1E). Besides minor tenderness of the maxillary wall, the patient had no residual complaints from the maxillary sinuses. Nasendoscopic evaluation showed no evidence of pathology. A CT-scan three months after functional endoscopic sinus surgery showed no evidence of pathology in the left maxillary sinus (Figure 1F). During a follow-up of 12 months no complaints related to the paranasal sinuses were noted, and no implants were lost.

Case 2

A 47-year-old man was referred to our hospital with complaints about his upper denture. Because of an extremely resorbed maxilla, retention and stability of his upper denture were very poor. The available bone volume was insufficient for reliable insertion of endosseous implants. Preoperatively, no signs of clearance-related maxillary sinus problems were noted. Bilaterally grafting to elevate the floor of the maxillary sinus and to increase the width of the alveolar crest was performed with autogenous iliac bone grafts. Cephradine (i.v. 1g, 3 times daily) was started 1 hour preoperatively and continued for 48 hours. Four days post-surgery, a submucosal swelling developed in the osteotomy region in the left maxillary wall (Figure 2A). Conventional radiographic examination revealed an opaque left maxillary sinus (Figure 2B). Examination of the oropharynx showed a postnasal drip.

The patient was referred to the ear, nose and throat (ENT) department for treatment of the maxillary empyema. An inferior meatus antrostomy and sinus lavage were performed, and a silicone drain was left in the maxillary sinus (Figure 2C). Lavages were continued for two weeks, and the patient needed antibiotic treatment (amoxycillin-clavulanate 500/125 mg, 3 times daily), continued for 2 weeks in combination with a mixture of decongestants (xylometazoline 0.1%), and topical corticosteroids (dexamethason 0.01%). After 3 weeks nasendoscopic evaluation showed complete recovery from the maxillary sinus empyema. In spite of adequate ENT intervention, the bone graft at the left side seemed to be insufficient for insertion of implants. A second bone grafting procedure (with bone grafts from the mandibular symphysis) was needed for reliable implantation (Figure 2D). After a follow-up period of 26 months, none of the implants had been lost, and there have been no paranasal sinus complications.
Figure 1
A 56 years old female with upper denture problems related to extreme maxillary resorption.

A Three weeks after maxillary sinus floor elevation surgery, X-Waters examination showed an opaque left maxillary sinus indicative for maxillary sinusitis.

B Six weeks after maxillary sinus floor elevation surgery. Despite of antibiotic treatment, inferior meatal antrostomy and sinus irrigation, the maxillary sinusitis, complaints had persisted. CT-scanning showed mucosal swelling of the left maxillary sinus and a free floating bone sequester in the left maxillary sinus.

C One month after middle meatal antrostomy and endonasal ethmoidectomy endoscopic evaluations showed complete recovery. Endoscopic view (0 degree rigid scope) of left nasal vestibulum. Entrance of the antrostoma in the middle meatus (arrows).
**Figure 1 (continued)**

**D** As Figure 1C. Endoscopic view (0 degree rigid scope) inside the left maxillary sinus, via middle meatal (fontanel) antrostoma (arrows). Middle turbinate (♦) and dorso-caudal ridge of the middle meatal (fontanel) antrostoma (f) are clearly visible. Recovery of the mucosal lining of the maxillary sinus (M), after surgical treatment.

**E** Orthopantomogram showing six implants inserted in the grafted area, and a removable prosthetic appliance in the lower jaw.

**F** CT-scan three months after functional endoscopic sinus surgery showed no evidence for pathology in the left maxillary sinus.
Figure 2
A 47-year-old male with upper denture problems related to extreme maxillary resorption.
A Four days after maxillary sinus floor elevation surgery, swelling was observed in the osteotomy area.
B Waters’ view four days after maxillary sinus floor elevation surgery showing an opaque left maxillary sinus.

Discussion
The risk of developing maxillary sinusitis can be reduced by preoperative radiographic examination (Waters’ view). These radiographs may reveal mucosal pathology in sinus clearance-compromised patients. However, the diagnostic value of the radiographs is rather low (73%) (Buijer 1976; Kennedy 1992). Nasendoscopic evaluation is indicated for patients with a history of frequent sinusitis to rule out the presence of an obstructive phenomenon as a risk factor before undergoing a sinus lift procedure. Because sinus clearance compromising factors were not evident, preoperative endoscopic evaluation was not performed. Although the
occurrence of iatrogenic sinus membrane perforations during surgery does not seem to be related to the development of postoperative sinusitis in healthy patients (Timmenga et al. 1997), large perforations of the maxillary sinus membraneous lining might result in a discharge of the bony fragments into the maxillary sinus and thus cause maxillary sinusitis. The influence of postoperative pressure of the upper denture on the buccal wall of the maxilla should be kept in mind as a possible factor in displacement of bony fragments into the maxillary sinus. In case 2, despite standard perioperative antibiotic treatment, contamination of haematoma in the osteotomy region probably caused maxillary empyema 4 days postoperatively. An extensive preoperative history and plain radiographic examination did not indicate any maxillary pathology. Sinus lavages solved this complication.
Endoscopic examination after this intervention showed complete recovery of the maxillary sinus, and no ostial pathology was observed. Contamination of the operative site by secondary infection of the maxillary sinus is therefore not very likely. Hypothetically, infection of the bone graft could have been attributable to oral contamination of the site as a result of a mucosal dehiscence. This could be the cause of complete loss of the bone graft in case 2.

If patients develop chronic maxillary disease after maxillary sinus floor elevation procedures special care is needed to prevent loss of bone grafts. Intervention is necessary to establish adequate drainage of the maxillary sinus and to remove sequestra that may be responsible for maintaining this undesirable condition. In Tables 1 and 2, guidelines for the treatment and prevention of transient and chronic sinusitis are given. These guidelines are based on the facts that:

1. Diminished maxillary sinus drainage is closely related to structural and mucosal factors responsible for the size of the maxillary ostium. Therefore all factors that disturb sinus drainage such as septal deviation, nasal polyposis, allergy, obstructive lung disease and infundibular pathology, have to be evaluated at pre-operative screening and treated accordingly before elevation surgery.
2. The risk on development of maxillary sinusitis is increased in patients with a disturbed clearance of the sinus.
3. In case of large perforations of the sinus membrane a considerable proportion of the grafted bone is exposed to the sinus environment. Because surgical treatment affecting the maxillary sinus will result in at least a transient sinusitis, the larger the exposed area, the greater the potential risk of infection and loss of the bone graft.

**Table 1** General guidelines for the treatment of transient and chronic maxillary sinusitis after elevation of the maxillary sinus floor.

<table>
<thead>
<tr>
<th>Transient sinusitis</th>
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<tr>
<td>1. Use of decongestants and antibiotics</td>
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<td>2. Follow-up after 2 weeks</td>
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<td>3. If no recovery, transient sinusitis has possibly evolved into subacute sinusitis needing further treatment:</td>
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<td>a. continuation of decongestants and antibiotics</td>
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<td>b. maxillary drains for sinus irrigation</td>
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<tr>
<td>c. CT-scanning and consideration of functional endoscopic sinus surgery, if no recovery within 3 weeks</td>
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<th>Chronic sinusitis</th>
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<tr>
<td>1. Use of decongestants and antibiotics</td>
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<tr>
<td>2. CT-scanning and functional endoscopic sinus surgery</td>
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</table>


**Table 2** General guidelines for the prevention of transient and chronic maxillary sinusitis after elevation of the maxillary sinus floor.

1. Preoperative evaluation of sinus clearance-related factors
2. Post-surgery: nasal decongestants (xylomethazolne 0.1%), and topical corticosteroids (dexamethasone 0.01%), to prevent post-surgery obstruction of the ostium
3. Perioperative antibiotic prophylaxis (cephradine i.v. 1 gram 3 times daily, starting 1 hour before surgery and continued 48 hours after surgery)

**References**


Chapter 5

Maxillary Sinus Floor Elevation Surgery

a Clinical, Radiographic and Endoscopic Evaluation

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Abstract

Although maxillary sinus floor elevation surgery with autogenous bone grafts has become a well established pre-implantology procedure, its effect on the function of the maxillary sinus has not been subject of prospective human studies. In this prospective study the effects of maxillary sinus floor elevation on maxillary sinus performance was evaluated.

17 consecutive patients underwent maxillary sinus floor elevation surgery with an iliac crest autogenous bone graft, agreed to participate in this study. All patients were subject to extensive anamnestic and clinical investigation on sinusitis, conventional radiography (Waters’ projection) and unilateral endoscopic inspection of the maxillary sinus. This triad of evaluations was performed preoperatively, immediately preceding the elevation procedure (maxillary sinus to be inspected endoscopically was randomly selected), and 3 (at insertion of the implants) and 9 months (at uncovering of implants) post-elevation.

5 out of 17 patients had a history of an impeded sinus clearance, but did not show clinical, or radiological signs of actual sinus pathology preoperatively, neither did the other 12 patients. By contrast, unilateral endoscopic evaluation revealed pre-existing subclinical mucosal pathology in 2 out of 5 patients with a history of sinus clearance impairment and in 1 out of the other 12 patients. 3 months post-elevation, clinical and radiographical examination showed chronic maxillary sinusitis in 1 non compromised patient. Moreover, serial unilateral endoscopic evaluation revealed subclinical maxillary mucosal pathology in 4 other patients (2 had a history of an impeded sinus clearance), confirmed by Waters’ projection in 3 of these 4 patients. Nine months post-elevation, only subclinical maxillary mucosal pathology was detected endoscopically in 2 patients (1 compromised, 1 non compromised patient), confirmed by Waters’ projection in this last patient. 5 implants were lost during the 9 months observation period.

As is obvious from this prospective evaluation, the effects of the sinus floor elevation procedure on maxillary sinus performance in patients without signs of maxillary sinusitis are of no clinical significance.
Introduction

Maxillary sinus floor elevation surgery with autogenous bone grafts has been proven to be a reliable pre-implantology method to enable insertion of endosseous implants in a severely resorbed edentulous maxilla (Raghoebbar et al. 2001). An often mentioned drawback of this procedure is the development of maxillary sinusitis after elevation surgery (Timmenga et al. 1997, 2001).

Maxillary sinus floor elevation exert a suggested potential hazard of compromising the sinus physiology because the maxillary physiology should be affected by the altered anatomical relation of the antral floor. In addition to the altered anatomy, mucosal injury and postoperative swelling may lead to reduction of the patency of the ostio-meatal unit, which plays a key role in the development of sinusitis, viz. impairment of the mucociliary cleansing system (Buiter 1976; Terrier 1991). If the patency of the maxillary ostium is reduced, or the maxillary sinus is (partly) filled up by post-operative hematoma or seroma, the development of a postoperative maxillary sinusitis may compromise the success of the sinus graft and/or implants and the patient’s sense of general physical well-being (Tos et al. 1984; Melen et al. 1986; Dawes et al. 1989; Schow 1991; Stierna et al. 1991; Norlander et al. 1993; Nord 1995; Lanza et al. 1997).

The clinical diagnosis sinusitis is characterized by a typical triad of symptoms, i.e. nasal congestion, pathological secretion or obstruction, and headache (Williams et al. 1993; Yonkers 1995). Detection of post-elevation maxillary sinusitis on conventional radiographs is difficult. Misinterpretation may easily occur, for example due to altered pneumatization and sinus depth as a result of the grafting procedure (Illum et al. 1972; Larenne et al. 1992; Wiltfang et al. 2000). Conversely, close inspection of the antral mucosa (the so-called Schneiderian membrane) with fiber-endoscopic tools nowadays is the standard method in Ear Nose and Throat (ENT) surgery and facilitates other diagnostic modalities like histology, cytology and microbiology (Herberhold 1973; Buiter 1976; Terrier 1991; Howard et al. 1986; Pfleiderer et al. 1986; Smith et al. 1988; Kamel 1989; Bavbek et al. 1997; Bonifazi et al. 1997; Westergren et al. 1998). Direct observation of the ostio-meatal unit and antrum is beyond doubt of great importance in the evaluation of sinus (clearance) pathology and diagnosing maxillary sinusitis.

The aim of this study was to prospectively evaluate the effects of maxillary sinus floor elevation surgery on maxillary sinus performance, applying anamnestic and clinical investigation, radiodiagnostic evaluation, and endoscopy.
Material and Methods

Patients

17 consecutive patients (11 women, 6 men; mean age 53±15 years at time of surgery, range 22-73 years) participated in this prospective study. All patients needed elevation of the maxillary sinus floor with autogenous bone grafts. Informed consent was obtained from all patients. For details with regard to planning of treatment see Raghoebbar et al. (2001).

To become included in this study patients had to suffer from (partial) denture problems related to a severely resorbed posterior part of the maxilla. The denture problems were evaluated by a team of two well experienced prosthodontics and two well experienced oral surgeons. Surgery and prosthodontics were performed within the same clinic. The maxilla was edentulous in 15 patients, and partial dentulous in 2 patients. In the mandible the edentulous patients wore implant-supported overdentures (n=5) or full dentures (n=4). 8 patients were (partially) dentulous in the mandible.

In case of a history of a disturbed clearance function of the maxillary sinus, patients were only included, if both clinical inspection and preoperative conventional radiographic examination (Waters’ projection) did not show signs of maxillary sinus pathology. In case of medical compromising factors, e.g. diabetes mellitus, internal screening and regulation was performed preoperatively. The endoscopic examination of the maxillary sinus performed in all patients was not part of the inclusion criteria, but was part of the experimental setup in this prospective study.

Clinical and radiographic examination

As part of the inclusion criteria, all patients were preoperatively subject to screening on sinusitis by applying a standardized extensive anamnestic questionnaire on sinus clearance compromising factors. Orthopantomograms and lateral cephalograms were made to assess the height of the maxillary alveolar bone, the dimensions of the maxillary sinus, and the antero-posterior relationship of the maxilla to the mandible. The vertical height of the alveolar bone between the most caudal part of the maxillary sinus and the oral cavity was on average 3±2 mm (range 1-5 mm). Occipito-mental projections (Waters’ projection) were made for detecting swelling of the maxillary mucosa. Both the clinical and radiographical examinations were repeated 3 (at insertion of the implants) and 9 months (at uncovering of the implants) after elevation.
Endoscopic examination of the maxillary sinus

Under general anesthesia, after decongestion of the nasal vestibulum that was not containing the nasotracheal tube, endoscopic examination of the nasal cavity and the infundibular area, with special interest on the ostio-meatal unit, was performed. Subsequently, via the inferior meatus, after medial luxation of the inferior turbinate, a trocar with cannule was inserted into the antral cavity (Figure 1). Endoscopic examination was performed with a rigid endoscopic optic (30 degree fiberoptic Storz, Germany). For documentation of the endoscopic views we used a Panasonic CCD camera, linked to a Sony video printer. As source of light a 160 W Xenon light fountain was used. After removing the cannule, the inferior turbinate was lateralized to its normal position. All endoscopic procedures were performed by the same well experienced ENT-surgeon.

Assessment of the mucosal aspect of the elevation area of the maxillary sinus, was based on a modification for endoscopic sinus evaluation, proposed by Petrusson (1982). A normal aspect of the sinus mucosa showing its delicate vascular aspect, without any sign of discharge or swelling was scored as grade 0 mucosal aspect. A hyperaemic aspect of the sinus mucosa was scored as grade 1, mucosal swelling as grade 2, and existence of discharge as grade 3. Grade 4 was scored in case the antral mucosa showed an aspect of severe inflammation with polyposis.

Endoscopic examination was performed during maxillary sinus floor evaluation surgery (preceeding the elevation), and 3 (at insertion of the implants) and 9 months (at uncovering of the implants) after elevation.

Figure 1  Endoscopic inspection of the left maxillary sinus. The rigid 30 degree endoscopic fiber optic is inserted in the antral cavity via the inferior meatus and provides close inspection of the maxillary sinus floor.
Maxillary sinus floor elevation surgery and insertion of implants

In all cases, the patients were treated under general anaesthesia and iliac crest bone grafts were used. Large autogenous cancellous bone grafts were harvested from the superior anterior medial part of the iliac crest. In all cases a two-stage procedure (first stage: bone grafting; second stage: placement of implants) was performed bilaterally. After elevation of the sinus floor, the width of the alveolar crest was increased by placing monocortical cancellous bone blocks buccal of the cortex of the alveolar defect, with the cancellous side of the bone graft in contact with the jaw (Raghoebar et al. 1993, 1997). Latter grafts were fixed with titanium screws to the alveolar bone. Cancellous bone particles were used to fill the small gaps between the bone graft and the alveolar crest.

Before harvesting the iliac crest bone grafts, the patients received broad spectrum antibiotics, (Cephradine 1 gram, 3 times daily), starting one hour preoperatively (intravenously) and continued orally for 48 hours after surgery. Postoperatively the patients received a 0.2% chlorhexidine mouth rinse (1 minute, 5 times daily) for 2 weeks, and nasal decongestion (Xylocathazoline 0.1%) for one week. One month postoperatively, the edentulous patients were allowed to wear dentures if possible, after relieving them in the operated areas and relining them with a soft liner. In the partially edentulous cases, there was no need for a temporary prosthesis.

After 3 months in total 85 titanium implants (Bränemark®, Nobel Biocare, Göteborg, Sweden) were inserted in the posterior region using a surgical template. 6 months after insertion the implants were uncovered, the oral mucosa thinned, and the abutments connected.

Prosthodontics

The patients were rehabilitated with implant-supported overdentures (n=15), or partial bridges (n=2).

Results

Anamnestic and clinical examination

Preoperatively

Anamnestic evaluation revealed that 5 out of 17 patients had a history of sinus clearance compromising factors. In agreement with the inclusion criteria, prior the
elevation procedure none of these 5 patients showed any sign of acute or chronic maxillary sinusitis. 2 of these 5 patients had a history of obstructive lung disease, 2 patients had a proven allergy for house dust mite, and 1 patient had an extensive history of cleft surgery.

**Postoperatively**
2 weeks postoperatively, 1 patient suffered from severe maxillary sinusitis at the not endoscopically evaluated left side. This patient was not known with a history of sinus clearance compromising factors. A middle meatal antrostomy and endonasal anterior ethmoidectomy were carried out at the ENT department to treat this complication. At the three months evaluation some mild left-sided prickle-like sensations existed, at the nine months evaluation all complaints had ceased. In the other 16 patients both anamnestic and clinically no sinus pathology was observed.

During the 9 months observation period in total 5 implants (5.9 %) were lost. All implants had a good primary stability, and there were no known clinical problems that might explain the reasons of loss of these implants. The lost implants were equally distributed over the left and right sinus region and not related to the endoscopic procedures.

**Radiographic examination**

**Preoperatively**
Waters’ projection showed in all 17 patients a clear maxillary sinus (Figure 2A).

**Postoperatively**
3 months post-elevation Waters’ projection showed post-grafting opacity of the maxillary sinus floor in all patients. Parietal maxillary mucosal thickening was observed in 4 patients. (Figure 2B). 2 of these 4 patients were known with a history of a compromised sinus clearance. The patient in whom maxillary sinusitis had developed post grafting showed complete opacity of the left maxillary sinus (Figure 2C). In addition, retention cysts of the maxillary sinus were observed in 2 patients (Figure 2D).

**9 months post-elevation**
Waters’ projection showed except from post-grafting opacity of the maxillary sinus, parietal mucosal thickening in 3 patients. All 3 patients had a history of sinus clearance compromising factors. In 2 of them, the mucosal thickening was also present at the three months evaluation. The patient who had suffered from maxil-
lary sinusitis early post-grafting still showed complete maxillary sinus opacity and atelectasis of the left maxillary sinus (Figure 2E). Finally, both cysts had persisted.

**Figure 2**
Conventional radiographic examination (X-Waters).
* A Preoperative situation showing a normal aspect of the maxillary sinus.
* B Situation 3 months post-elevation showing post-grafting opacity of the right maxillary sinus floor. Note the parietal maxillary mucosal thickening (arrows), observed in 4 patients.
Figure 2 (continued)
Conventional radiographic examination (X-Waters).
C Situation 3 months after sinus floor elevation surgery. Chronic maxillary sinusitis, showing nearly complete opacity of the left maxillary sinus (observed in 1 patient).
D Mucosal cyst formation (arrows) in the right maxillary sinus.
Endoscopic examination

Preoperatively
In 14 patients endoscopical unilateral examination showed a normal mucosal aspect (Table I, Figure 3A). In 3 patients antrostomic evaluation showed an abnormal mucosal aspect of the maxillary sinus. 2 of them were known with a history of a compromised sinus clearance (Figures 3B, 3C).

Postoperatively
3 months postoperatively, unilateral endoscopic evaluation showed in 4 patients a mucosal divergent aspect (Table I). A grade 0 endoscopic score was found in 2 patients with prior existing preoperative pathological maxillary sinuses, indicating complete recovery of the maxillary sinus (Figure 3D). 3 of the 4 patients with a mucosal divergent aspect had a history of a compromised clearance.

9 months post-elevation, in 2 patients grade 2 mucosal aspect could be detected, which in one of them also was observed preoperatively and at the 3 months endoscopic evaluation (Table 1).
Table 1  Antroscopic results, preoperative, and at 3 months and 9 months evaluation. Preoperative anamnestic clearance compromised factors were observed in patients 1-5, viz. COPD (patients 1, 2), allergy (patients 1, 4, 5), paranasal surgery (patient 1, 5) and cleft lip and palate (patient 3).

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sinus*</th>
<th>Preop.</th>
<th>3 Months</th>
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Endoscopic score
0 = normal
1 = hyperemia
2 = swelling
3 = discharge
4 = polyposis

*L: left maxillary sinus; R: right maxillary sinus

Comparison of Waters’ projection and unilateral endoscopy
Preoperatively subclinically sinus pathology was not detectable on radiographs in 3 patients, while at three and nine months evaluation disagreement between the endoscopic and radiographic results existed in 1 and 3 patients, respectively.
Figure 3
Endoscopic examinations (30 degree fiber optic) of the maxillary sinus.

A Preoperative situation showing a normal aspect of the maxillary sinus.

B Preoperative endoscopic examination of the right maxillary sinus of a patient with COPD showing mucosal thickening of the maxillary sinus mucosa (grade 2), possible as a result of sinus clearance impairment.
Figure 3 (continued)
Endoscopic examinations (30 degree fiber optic) of the maxillary sinus.

C Preoperative endoscopic aspect of the right maxillary sinus showing mucosal polyposis of the mucosa (grade 4); compromised patient with cleft lip and palate.

D Normal aspect of the maxillary sinus mucosa (grade 0), covering the grafted maxillary sinus floor, 3 months post-elevation (arrows).
Discussion

This study is the first study reported in literature investigating the effects of elevation of the floor of the maxillary sinus with autogenous bone grafts on maxillary sinus performance applying clinical, radiographical and endoscopical techniques. From this prospective study it is obvious that maxillary sinus floor elevation surgery results in neglectable signs of sinus pathology. In most cases no clinical problems occurred, and in the one patient who developed sinusitis the symptoms vanished after treatment.

A maxillary sinus floor elevation procedure reduces the volume of the maxillary sinus. As a result of the iatrogenic damage caused by raising the maxillary membraneous lining, a transient or persisting effect on the ciliated antral mucosa could be expected. Among others, when the maxillary sinus is filled up with blood, structural delay of the maxillary sinus clearance is thought to occur. This might result in blocking of the ostio-meatal unit, which is a potential risk on development of sinusitis. However, the results of this study showed that clinical signs of sinusitis developed in only one patient. This indicates that a normal maxillary sinus at the time of surgery seems to have a high potency to regain its function post surgery.

Although no clinical signs of sinus pathology were observed in the fast majority of the patients, endoscopic examination revealed that the surgical procedure apparently in few patients resulted in changes at the level of the maxillary mucous membrane, which had mostly a mild character. Such mild deviations of the maxillary mucous membrane may be a result of the dynamic course of the maxillary sinus mucosal activity as function of the innate airway tissue defense system (Wanner et al. 1996; Erjafelt et al. 1997; Tomee et al. 1997; Kauffman et al. 1998; Tomee 1999). The mucosal airway defense of healthy individuals in general is a highly efficient system for the elimination of inhaled small particles and/or microorganisms. The ciliated epithelial lining of the maxillary sinus is not only a first line physical barrier preventing penetration, the coordinated ciliary movement of ciliated epithelial cells transporting an epithelial lining fluid in which impacted particles and microorganisms highly efficient are eliminated. Release of nitric oxide by ciliated epithelial cells reinforces the defensive effectivity (Kauffman et al. 1998; Jeong-Whun Kim et al. 2001). Mucosal injury and post operative swelling as can be expected after sinus floor elevation surgery may influence the mucociliary barrier function and effectiveness of the cleansing system, resulting in divergent radiographic and/or (subclinical) endoscopic findings. Specially in clearance com-
promised patients, this balance system of aggressive and defensive forces is expected to be vulnerable, as represented by endoscopic findings grade 3 and 4. A proper anamnestic assessment of pre-existing sinus clearance impairment may detect patients who are at risk for an impaired recovery of the maxillary sinus (mucosa) following elevation. However, this is no conditio sine qua non as 2 patients with pre-existing, endoscopically detected subclinical changes of the antral mucosa but without clinical and radiological signs of sinus pathology at the time of surgery, showed complete recovery of the antral mucosa, at 3 and 9 months post-elevation endoscopic evaluation. Therefore, the existence of a (very) mild inflammatory mucosal aspect as observed by endoscopy is not a strict contraindication for surgery, but should be interpreted as a normal activity of the mucosal airway defense system as can be observed in healthy, nonoperated human, in general. In addition, endoscopic mucosal appearances not always correspond to the histopathologic changes of the maxillary mucosa (Mann et al. 1979; Kamel 1989; Stierna et al. 1990), and even the fact that the maxillary sinus in healthy state, is not sterile supports the discrepancy between endoscopical findings, and mucosal pathology (Hartog 1997; Posawetz et al. 1991; Rong-San Jiang et al. 1999).

Summarizing the results of this study supports the following guidelines for planning sinus floor elevation surgery in patients without anamnestic or clinical signs of sinusitis:

- In case of a clear Waters’ projection, sinus floor elevation surgery can be performed.
- In case of maxillary sinus opacification as assessed on a preoperative Waters’ projection, endoscopical examination indicated. This to rule out structural sinus clearance impairment. If a normal, or mild mucosal inflammatory aspect of the antral mucosal is found, without any sign of pathology in the infundibular area (containing the ostio-meatal unit), sinus floor elevation surgery can be performed.

References


Chapter 6

Effects of Maxillary Sinus Floor Elevation Surgery on Maxillary Sinus Physiology

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Abstract

In a prospective study, the effects of elevation surgery of the maxillary sinus floor on maxillary sinus physiology were assessed. Seventeen consecutive patients without preoperative anamnestic, clinical and radiological signs of maxillary sinusitis underwent sinus floor elevation surgery with iliac crest bone grafts. All patients were subjected to unilateral endoscopic examination of the maxillary sinus, taking of a biopsy specimen from the sinus floor mucosa, and collection of a sinus lavage-fluid aspirate. This triad of evaluations was performed immediately preceding the elevation procedure, and three months (at implant insertion) and nine months (at uncovering of implants) postoperatively. All procedures were performed under general anaesthesia. Preoperatively, three out of 17 patients showed pre-existing mucosal pathology endoscopically, while the three and nine months results revealed the presence of mucosal pathology in four and two patients, respectively. The three months microbiological evaluation showed a significant increase of cultures with bacterial growth, while the nine months culture results were comparable to the preoperative status of the maxillary sinus. Morphologically, neither fibrosis nor an altered inflammatory response or thickening of the epithelium and lamina propria was observed postoperatively. The number of goblet cells in the epithelial layer was increased. From this study it is concluded that the effect of maxillary sinus floor elevation surgery with autogenous bone grafts does not appear to have clinical consequences in patients without signs of pre-existing maxillary sinusitis.
Introduction

Maxillary sinus floor elevation surgery with autogenous bone grafts has proven to be a reliable method to enable insertion of endosseous implants to support an upper denture in patients with a severely resorbed maxilla or who have functional denture problems because of other reasons (Timmenga et al. 1997; Van den Bergh et al. 2000; Ten Bruggenkate and Van den Bergh 2000; Raghoebbar et al. 1993, 2001). Maxillary sinusitis after this procedure was considered to be the major drawback, although many results were based on non-clear criteria for examination and diagnosis of maxillary sinusitis (Doud Galli et al. 2001). When using general accepted Ear Nose and Throat (ENT)-criteria for diagnosing sinusitis, however, development of post elevation chronic maxillary sinusitis has been reported to occur in 1.3% of the patients who underwent such a procedure (Timmenga et al. 2001).

Although not many patients develop maxillary sinus pathology related complaints after sinus floor elevation surgery, this procedure carries the inherent risk of compromising sinus physiology. It is generally assumed that the maxillary sinus physiology is affected by the altered anatomy i.e. the lifted sinus floor in combination with a bulging or injured subsurface of the lifted sinus mucosa. Mucosal swelling may also lead to reduction of the patency of the ostio-meatal unit. This unit plays a key-role in the development of sinusitis, viz. by impairment of the mucociliary cleansing system (Bertrand and Eloy 1992). If the maxillary sinus is (partly) filled up by haematoma or seroma and/or the patency of the maxillary ostium is reduced, maxillary sinusitis might develop compromising the success of the grafting procedure.

In order to gain objective data on possible sinus pathology following sinus floor elevation surgery with iliac crest bone grafts, a prospective, endoscopic, microbiologic and morphologic examination of the maxillary sinus was carried out in patients without preoperative signs of maxillary sinusitis. Direct observation of the ostio-meatal unit and the mucosal lining of the maxillary sinus are of great importance in the evaluation of sinus (clearance) impairment and in diagnosing maxillary sinusitis. It also facilitates other diagnostic means like biopsy, cytological smears and cultures (Pfeiderer et al. 1986; Bavbek et al. 1997).
Materials and Methods

Patients
Seventeen consecutive patients (11 women, 6 men), with a mean age at time of surgery of 53±15 years (range 22-73), were included in this prospective study. All patients were referred to the department of oral and maxillofacial surgery of the Groningen University Hospital because of poor retention of the (partial) upper denture related to severe resorption of the posterior maxilla. The patients were examined by two experienced prosthodontists and two experienced oral and maxillofacial surgeons. The maxilla was edentulous in 15 patients, and partially dentate in two patients. In all patients sinus floor elevation surgery with autogenous bone grafts was indicated. Surgery and prosthodontic aftercare were performed within the same clinic. Informed consent was obtained from all patients.

As part of the inclusion criteria, all patients were preoperatively subjected to anamnestic screening for sinus clearance compromising factors using a standardised questionnaire. Clinical examination of the patients was performed by rhinoscopy to examine the condition of the nasal mucosa, while nasendoscopy was performed for inspection of the ostio-meatal unit. Patients were considered to suffer from maxillary sinusitis in case of mucosal redness and oedema of the nasal mucosa, and presence of mucopurulent discharge around the maxillary ostium (Yonkers 1992). Although CT-scanning would have provided more detailed information, conventional radiography (Waters’ projection) was used in this study. The potential risk of damaging eyes of healthy humans by the high radiation dose from CT-scanning was found to be a conclusive ethical objection. Furthermore, it has been shown that a combination of nasoendoscopy and Waters’ projection is a generally accepted diagnostic procedure to rule out structural sinus clearance impairment despite a sensitivity of Waters’ projection for diagnosing maxillary sinusitis of 85% (Timmenga et al. 2002).

Patients with a history of a disturbed clearance function of the maxillary sinus were included only in case of absence of preoperative clinical and radiographic signs of actual sinusitis. In case of other medical compromising factors, e.g. diabetes mellitus, internal screening and regulation were performed preoperatively.
Experimental design

In all patients, sinus floor elevation surgery was performed bilaterally with iliac crest bone grafts as was described by Raghoobar et al. in 1993 and 2001. Three months post-elevation, implants were inserted followed by uncovering of the implants six months later. Prior to the elevation procedure, implantation and uncovering procedure unilaterally endoscopic inspection of the maxillary sinus was performed with a rigid nasal endoscopic optic (Figure 1). Subsequently, a biopsy of the mucosal lining of the maxillary sinus floor was taken with a small forceps (Figure 1a) via the introduced cannula, followed by aspiration of sinus lavage-fluid using a disposable mucus suction set (Figure 1b) to collect a microbiological sample. The biopsy was taken first to prevent ciliary damage by manipulating with the suction cannula in the antral cavity. The cannula is directed to the lateral-caudal sinus wall by introducing the trocar via the inferior meatus into the maxillary sinus (Figure 1). All biopsies were taken from that small area of the latero-caudal antral wall. Hardly any bleeding occurred which made a reliable microbiological sampling procedure possible in all cases.

Endoscopy

Under general anaesthesia, after decongestion of the nasal cavity, endoscopy of the middle meatus with special emphasis on the infundibular area was performed (Figure 1). The examination side was randomised for the first inspection, while the same side was used again for the three and nine months evaluations. After medialisation of the inferior turbinate, a trocar was inserted via the inferior meatus into the antral cavity. Endoscopic examination was performed with a rigid endoscopic optic (30 degree Storz Germany), linked to a Panasonic CCD camera, and Sony video printer. All endoscopic procedures were performed by the same experienced ENT-surgeon.

Assessment of the mucosal aspect of the elevation area of the maxillary sinus was based on sinuscopic assessment, as proposed by Petruson (1982) and modified by Westergren et al. (1998). A normal aspect of the sinus mucosa showing its delicate vascular patterns, without any sign of discharge or swelling was scored as a grade 0. A hyperaemic aspect of the sinus mucosa was scored as grade 1, mucosal swelling as grade 2, and existence of discharge as grade 3. Grade 4 was scored in case the antral mucosa showed severe inflammation with polyposis.
**Figure 1** Via the infra-meatal fossa a trocar is inserted into the antral cavity. A 30-degree rigid endoscope is introduced through the cannula. Its viewing field is highlighted, but can be adjusted by rotating the endoscope. After inspection a small forceps biopsy specimen was taken from the latero-caudal antral wall (blue line), for histological examination and sinus lavage-fluid was aspirated with a suction set for microbiological examination, both via the cannula.

*a* Biopsy forceps, *b* Suction set.

**Surgery and prosthodontics**

In all patients bilateral sinus floor elevation procedures were performed with iliac crest (blocks and particulate) bone grafts according to the procedure described (Raghoebhar et al. 1993, 2001). The grafts were harvested from the superior anterior medial part of the iliac crest. Block grafts were placed on the floor of the elevated sinus membrane and used as a buccal onlay if the width of the alveolar crest was too small. The remaining spaces around the block grafts were filled with particulate bone. Before harvesting the bone grafts, all patients received anti-microbial
prophylaxis (cephradine 1 g, 3 times daily), starting one hour preoperatively (intra-
venously) and continued orally for 48 hours after surgery. Postoperatively, the
patients received a 0.2% chlorhexidine mouth rinse (1 min, 5 times daily) for two
weeks. After three months, titanium implants (Brånemark, Nobel Biocare, Göte-
borg, Sweden) were inserted using a surgical template. Six months after insertion
the implants were uncovered, the oral mucosa was thinned if applicable and the
abutments were connected. The patients were provided with implant supported
 overdentures (n=15) or partial bridges (n=2).

**Morphology**

When taking a biopsy of ciliated mucosa, one is running a risk to mechanical dam-
age of tissue structures, e.g. ciliae. Ciliary damage is a common finding when per-
forming histomorphological examination of maxillary mucosal biopsy specimen of
patients with sinusitis (Hinni et al. 1992; Westrin et al. 1992). A difference between
mechanically damaged ciliae and ciliary damage caused by sinusitis can be made by
precise light and electron microscopic examination of the antral epithelium and
submucosa. All preoperatively obtained biopsies were examined with special at-
tention to iatrogenic damage caused by the biopsy technique. The outcome was an
undisturbed ciliated aspect in all cases. Probably the bulky aspect of the mucosal
sample and the performance of the sinus lavage after taking the biopsy have
minimised the risk on iatrogenic ciliary damage.

Endoscopically obtained biopsies were rinsed in saline and placed into a fixa-
tive containing 2% glutaraldehyde buffered with 0.1 M sodium cacodylate buffer
(pH 7.4). The tissue specimens were then subdivided into two approximately equal
samples. One sample was used for scanning electron microscopy (SEM) and the
other sample was used for light microscopy (LM) as well as transmission electron
microscopy (TEM).

For SEM, the samples were additionally fixed with 1% osmium tetroxide for
one h, followed by dehydration in graded concentrations of ethanol and critical
point dried in liquid CO₂. The samples were then glued onto aluminium stubs with
fast curing epoxy resin, sputter coated with gold/paladium in a Balzer Union
sputtering device (Balzer Union, Furstentum Lichtenstein) and examined in a Jeol
Fe-SEM 6301-F scanning electron microscope (Jeol Ltd., Tokyo, Japan), operated
at an accelerating voltage of 2 kV. For LM and TEM, the tissue samples were
postfixed in a mixture of 1% osmium tetroxide/K₄FeCN₆ for one h, dehydrated in
graded series of ethanol and propylene-oxide and embedded in Epon (Serva Fein-
biocemica GmbH., Heidelberg, Germany). From all blocks, four midsagittal
smethin sections, each 1 μm thick, were prepared using a diamond histo-knife and a Reichert-Jung OMU4 ultra-microtome (Vienna, Austria). The smethin sections were stained with toluidin blue, and evaluated with LM for morphological analysis, and photomicrowgraphed using a Zeiss photomicroscope (Zeiss, Oberkochen Germany).

For TEM analysis, ultrathin (40-60 nm) sections adjacent to the smethin sections were cut, stained with uranyl acetate and lead citrate, and examined with a Philips CM-100 transmission electron microscope.

Quantitative or semi-quantitative LM assessment of the morphological aspect of the endoscopically obtained biopsy specimens was based on histologic criteria described in literature (Ham and Cormack 1987). With a High Power Field (HPF) magnification (400x), using ocular 10x and objective 40x, maxillary mucosal biopsy specimens were evaluated. In a randomized order an experienced histologist and a pathologist independently examined all slides. Morphologic assessment of the epithelium included its thickness scored as ‘normal’ (2-5 cell layers), or ‘thickened’ (5 or more cell layers), and the ciliated aspect of the epithelium was scored as ‘normal’ or ‘abnormal’ (i.e. absence or damaged cilia). The number of goblet cells per 100 epithelial cells (goblet-cell ratio) was counted. Counting the number of inflammatory cells per HPF (including polymorphonuclear cells PMN’s), lymphocytes, plasma cells and mast cells assessed the inflammatory response of the epithelial cell layer. The basal lamina was assessed with regard to its thickness, (‘not visible’ or ‘clearly visible’). The connective tissue aspect of the submucosa (lamina propria) was scored as ‘areolar connective tissue’, ‘dense connective tissue’ or ‘presence of fibrosis’). Counting the number of inflammatory cells per HPF (including PMN’s, lymphocytes, plasma cells and mast cells) assessed its inflammatory response. The presence of blood vessels (vascular response) and seromucous glands were scored as ‘absent’, ‘a few’ or ‘many’.

Microbiology

In clinical (ENT)-practice, microbiological examination is generally performed by antral needle aspiration (antral tap) or sinus endoscopy via the nasal inferior meatus (Van Cauwenberge and Ingels 1996; Vogan et al. 2000). Antral cultures can be obtained via the canine fossa as well, but such a procedure has the inherent risk of oral contamination as well as that long lasting discomfort has been reported after this procedure (Bernal-Sprekelsen et al. 1991; Rong San Jiang et al. 1999). As endoscopy was part of our study it was chosen to obtain microbiological samples by endoscopic sinus lavage.
After randomised unilateral inspection of the maxillary sinus and taking the mucosal biopsy, the content of a 5 mL syringe, filled with saline 0.9%, was introduced into the sinus via the cannula. Subsequently, the lavage fluid was collected using a sterile disposable mucus suction set (International Medical Products 990305, Zutphen, The Netherlands) introduced into the sinus via the same cannula. Microbiologic sampling was performed according to the procedure described by Isenberg (1992). Culturing of the samples was carried out according to a standardised method (Murray et al. 1999). After collection of maxillary sinus fluids in the suction set container, the specimen arrived at the department of medical microbiology within half an hour. First, the specimen was centrifuged for 10 seconds, and plated onto 5% blood sheep- and chocolate-agar, for incubation in 10% CO₂ and sabouraud- and MacConkey-3-agar for incubation in ambient air. All agar plates were incubated for 48 hours. For anaerobic culturing, the specimen were inoculated onto brucella blood-, bacteroides-bile-, kanamycin-vancomycin laked blood- and phenylethyl alcohol agar and incubated for 5 days under anaerobic conditions. Established methods were used to identify anaerobic and aerobic microorganisms. Numbers of micro-organisms were estimated semi-quantitatively by a selected group of trained laboratory workers. When micro-organisms were detected after one week of incubation time, culture results were scored as ‘positive’. In ‘negative’ cultures, micro-organisms were not present after one week.

Statistical analysis

Statistical analysis was performed using SPSS-10 for PC. Differences between morphological scores of the epithelium, basal lamina and sub-mucosa obtained before sinus floor elevation surgery and three and nine months following elevation surgery were tested with the Friedman test for more than two related samples. Microbiologic outcomes were assessed applying the Wilcoxon signed ranks test for two related samples.

Results

Patients (Table 1)

Preoperative characteristics

Five out of 17 patients had a history of sinus related pathology. Two of them had a history of obstructive lung disease, two patients had a proven allergy for house
Table 1 Results of unilateral microbiologic culture (C), radiographic (X), and endoscopic (E) examination before surgery and three and nine months following elevation surgery. Preoperatively clearance compromised factors were anamnestically present in patients 1-3, viz. COPD (patients 1, 2), allergy (patients 1, 4, 5), paranasal surgery (patient 1, 5) and cleft lip and palate (patient 3).

<table>
<thead>
<tr>
<th>Patient</th>
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<th>3 months</th>
<th>9 months</th>
</tr>
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<td></td>
<td></td>
<td>C</td>
<td>X</td>
<td>E</td>
</tr>
<tr>
<td>1</td>
<td>L</td>
<td>+</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>R</td>
<td>--</td>
<td>--</td>
<td>2</td>
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<tr>
<td>3</td>
<td>R</td>
<td>--</td>
<td>--</td>
<td>4</td>
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<tr>
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<td>R</td>
<td>+</td>
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<td>L</td>
<td>--</td>
<td>--</td>
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<tr>
<td>6</td>
<td>L</td>
<td>--</td>
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<td>7</td>
<td>L</td>
<td>--</td>
<td>--</td>
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<tr>
<td>8</td>
<td>L</td>
<td>--</td>
<td>--</td>
<td>0</td>
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<tr>
<td>9</td>
<td>L</td>
<td>+</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>R</td>
<td>--</td>
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<td>0</td>
</tr>
<tr>
<td>17</td>
<td>L</td>
<td>+</td>
<td>--</td>
<td>0</td>
</tr>
</tbody>
</table>

C: Culture score: negative --, positive +
X: Radiographic score: clear sinus --, mucosal thickening +
E: Endoscopic score: normal 0, hyperaemia 1, swelling 2, discharge 3, polyposid 4.

Dust mites; one of them had undergone paranasal surgery some years before. One other patient had a history of cleft surgery.

Post-operative characteristics
Two weeks post-operatively, one patient suffered from severe maxillary sinusitis on the side that was not endoscopically evaluated. This patient did not have a history of sinus clearance compromising factors. Under general anaesthesia, a middle meatal antrostomys and endonasal ethmoidectomy were carried out to treat this complication. At the three months evaluation, some mild prickle-like sensations existed, while conventional radiographic evaluation showed opacity of the involved maxillary sinus. At the nine months evaluation, all complaints had disap-
peared, although radiography still showed opacity and atelectasis of the maxillary sinus.

At the three months post-operative evaluation, none of the other 16 patients showed symptoms or clinical signs of sinus pathology. Radiography (Waters’ projection) showed post-grafting opacity of the maxillary sinus floor in all patients. In four patients (two of whom had a history of a compromised sinus clearance) thickening of the parietal maxillary mucosa was observed as well. Retention cysts of the maxillary sinus were observed in two other (non-compromised) patients.

Nine months post-elevation, none of the 17 patients had any clinical sign of maxillary sinusitis. In addition to the post-grafting opacity of the maxillary sinus, Waters’ projection showed thickening of the parietal mucosa in three patients, all of them having a history of sinus clearance compromising factors. Retention cysts of the maxillary sinus were observed in the same two patients as reported for the three months evaluation.

Endoscopy (Table 1)

Preoperative characteristics
In 14 patients endoscopic unilateral examination showed a normal mucosa. In two patients mucosal swelling (grade 2) and in one patient antral polyposis (grade 4) were present. Two of these three patients were known with a history of a compromised sinus clearance.

Postoperative characteristics
At the three months follow-up, unilateral endoscopic evaluation showed a mucosal divergent aspect (grade 1 or more) in four patients. Three of these patients had a history of a compromised clearance. A grade 0 (normal) endoscopic score was found in two patients who showed preoperatively a deviant score.

Nine months after elevation surgery, swollen mucosa (grade 2) could be detected in two patients. In one of them, this grading had also been observed preoperatively as well as at the three months endoscopic evaluation.

Light microscopy

Pre-elevation
With regard to the morphological aspect, LM examination showed a healthy ciliated aspect and normal thickness of the epithelium in all 14 patients with endoscopically normal (grade 0), as well as in the other three patients with endoscopically abnormal aspect (grade 2 and 4) of the maxillary mucosa (Figure 2A).
The mean goblet cell-ratio (number of goblet cells per 100 epithelial cells) was 20±13.5 (95% confidence interval of difference 13.4-27.4). In most patients only a few (0-3) mononuclear cells (lymphocytes) per HPF were observed in the mucosa. The basal lamina was visible in one patient only. In the submucosa between 5 and 35 inflammatory cells per HPF (mostly lymphocytes) were detected (mean 17.4±9.1; 95% confidence interval of difference 12.8-22.1). Submucosal glands were absent in most of the specimens. Thirteen patients showed the existence of areolar connective tissue. In four patients ‘dense’ connective tissue was found. None of the patients showed fibrosis.

**Three months post-elevation**
In comparison with the preoperative situation, the thickness and ciliated aspect of the epithelium had not changed (Figure 3A). However, there was a non-significant tendency that the mean goblet cell-ratio had increased (mean 28.0±15.6; 95% interval of confidence 20.5-36.6). The basal lamina was thickened (i.e. clearly visible) in six of the 17 patients. The submucosal inflammatory response did not show a (significant) difference in number of mononuclear cells (mean 20.3±10.8; 95% confidence interval 14.7-25.8). The number of blood vessels had not changed compared with the preoperative results. The connective tissue integrity did not show any difference compared with the preoperative findings and submucosal fibrosis was not observed.

**Nine months post-elevation**
Of all evaluated morphological parameters, only the goblet cell-ratio showed a significant increase compared with the pre-elevation data (mean 43.7±24.7; 95% confidence interval 31.1-56.5). In none of the evaluated patients fibrotic connective tissue was found (Figure 3B).

**Electron Microscopy**

**Pre-elevation**
With SEM and TEM examination a normal ciliated epithelium and goblet cells with normal intercellular adherence with desmosomes interconnecting the cells were observed preoperatively (Figures 3C, 3D).
Figure 2
Histomorphological aspects of the antral mucosa pre-elevation.
A LM image of the maxillary sinus mucosa is showing a normal pseudodstratified ciliated epithelium. A few goblet cells are present (arrowheads). In the submucosa a few inflammatory cells are visible (arrows). Submucosal glands are not found in this specimen. The submucosa consists of areolar connective tissue. (Toluidin blue staining; Bar = 45 μm).
B SEM image showing a normal ciliated epithelium, with a few nucleus producing goblet cells (asterisk). Bar = 2 μm.

Three months post-elevation
The ciliated aspect of the epithelial surface showed extensive presence of microvilli as well. This surface aspect was not found in the preoperative specimen. An
increase in number of goblet cells and presence of (branched) microvilli was observed (Figures 3E, 3F). The 9/2 aspect of the cilia (nine pairs of peripheral microtubules, around two central microtubules) showed findings of occasional abnormalities of this 9/2-architecture. Especially compound cilia (cilia consisting more than the normal ‘9/2’ micro-tubular subunits) were noticed. This deviated aspect of the 9/2-architecture has previously been described in healthy respiratory mucosa and in bronchial epithelium of heavy smokers (Rossman et al. 1984).

Nine months after elevation
Both the TEM and SEM evaluation showed normal ultrastructural aspects of the epithelium and submucosa (Figures 3G, 3H).

Bacteriology (Table 2)
Pre-operative observations
Evaluation of the cultures taken prior to the elevation procedure revealed that 11 out of 17 maxillary sinus cultures were negative, two samples showed polybacterial growth and in four cultures a monoculture of bacteria was found.
Three months post-elevation observations
Three cultures were found to be negative. In seven cultures a polybacterial growth was found. In seven other cultures monobacterial growth was detected. Thus,
Figure 3 (continued)
Histomorphological aspects of the antral mucosa three months post-elevation.

C  SEM image, showing an increased number of mucous producing goblet cells (asterisk). Bar = 4 μm.

D  TEM image showing a ciliated epithelial cell between two goblet cells (G). Some branched microvilli (arrow), are present on the surface of the ciliated cell. Bar = 2,5 μm.

when compared with control sinus, there was a significant increase in positive culture results three months after elevation (p<0.05).
Figure 3 (continued)
Histomorphological aspects of the antral mucosa three months post-elevation (continued).

E TEM image showing release of mucus producing goblet cell (asterisk). Bar = 1.6 μm.

F TEM image showing release of mucus producing goblet cell (asterisk). Bar = 1.6 μm.
Figure 3 (continued)
Histomorphological aspects of the antral mucosa three months post-elevation (continued).

**SEM** image nine months post-elevation showing mucus producing goblet cells (asterisk) surrounded by healthy ciliated cells. (Bar = 10 μm)

**TEM** image nine months post-elevation showing a normal aspect of the epithelium (E), basal lamina (Bm) and submucosa (Sm). (Bar = 4.4 μm)
Table 2  Culture results of sinus aspirates.*

<table>
<thead>
<tr>
<th>Side</th>
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<td>L.</td>
<td>1</td>
<td>CNS</td>
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<tr>
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<td>B. frag.</td>
<td>Gram+ cocci</td>
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<tr>
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<td>S. aur.</td>
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<tr>
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<tr>
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<tr>
<td>R.</td>
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* meaning of abbreviations:
- CNS: Coagulase-negative staphylococci
- H. infl.: Haemophilus influenzae
- B. frag.: Bacteroides fragilis
- Str.vir.: Streptococcus viridans
- E. coli: Escherichia coli
- S. aer.: Staphylococcus aureus
- M. cath.: Moraxella catarrhalis
- Anaer./Aerob.: Anaerobic/Aerobic bacteria
- Fusobact: Fusobacteriae
- Klebsiella: Klebsiella pneumoniae
- Proteus: Proteus mirabilis

**Patient developed chronic maxillary sinusitis at the contralateral, not endoscopically examined, left side.

Nine months post-elevation observations
At implant insertion, eight out of 17 cultures were found to be negative. In two cultures polybacterial growth was found, while in seven other cultures monobacterial growth was detected.
Discussion

This report is the first prospective evaluation of sinus physiology in patients, who had no signs of maxillary sinusitis prior to sinus floor elevation surgery, using autogenous bone grafts. It became clear that only negligible mucosal reactions were seen after elevation surgery of the maxillary sinus floor. Only one patient developed purulent maxillary sinusitis that needed functional endoscopic surgery.

The rather low complication rate is somewhat surprising. A transient or persisting effect on the ciliated antral mucosa could be expected as result of maxillary sinus floor elevation surgery raising the maxillary membrane. Especially, when the maxillary sinus is filled up with blood, delay of the maxillary sinus clearance is thought to occur, because it is generally assumed that a reduction of the patency of the ostio-meatal unit is a potential risk for the development of sinusitis. The results of this study, however, suggest that the maxillary sinus mucosa is capable to adapt adequately to the changes induced by elevation procedure, especially in cases of non-compromised sinus clearance (Stammberger 1986; Jensen et al. 1998).

Endoscopic examination revealed that the surgical elevation procedure resulted in mild changes to maxillary mucous membrane in a few patients. These changes may even be the result of the physiologic dynamic course of the maxillary sinus mucosal activity as a function of the airway tissue defence system in humans (Kauffman and Tomee 1998). Postoperative swelling, as can be expected after sinus floor elevation surgery, may influence the mucociliary barrier function and increase its vulnerability. The three months post-elevation morphological examination revealed complete recovery of the maxillary sinus physiology in all patients but one. The existence of a mild inflammatory reaction, as observed by endoscopic evaluation, should be interpreted as a normal physiologic activity of the mucosal airway defence system. This is comparable to the diffuse mucosal reaction of the sinus mucosa that can be observed in healthy, non-operated human beings (Smith and Cable 1988; Kauffman and Tomee 1998).

Since bacterial cultures are used for microbiological examination of the maxillary sinus, many studies have been performed showing the presence of a wide variety of aerobic and anaerobic bacteria. In most cases the patients in these studies suffered from acute or chronic maxillary sinusitis. The microbiologic status of the maxillary sinus in healthy individuals was recently described (Jiang et al. 1999), and it appeared that the healthy maxillary sinus is not sterile, as was also confirmed in this study. The definition of a healthy maxillary sinus, however, varies in many studies. This definition was based on the anamnestic absence of pathology, on the
absence of radiographic signs of pathology or on the absence of endoscopic signs of pathology. The sinus fluid collecting technique of these studies is also quite variable, which makes reliable comparison of these results impossible. When dealing with microbiological studies, one should consider that patient selection, duration of disease, previous medical treatment, change of bacterial growth during disease, culture-transport and cultures-technique all are important influential factors (Verschraegen 1998). Comparison of culture results of sinus aspirates showed to be as good as results of specimen obtained by sinus endoscopy (Casiano et al. 2001). The increase of bacterial growth three months after sinus floor elevation might possibly be the effect of the surgical procedure, which affected the maxillary mucosal lining and especially the mucosal defence system. A (mildly) decreased sinus clearance probably facilitates the temporary presence of micro-organisms. Vascular injury following surgery, mucosal swelling, the presence of old blood and a decrease of the patency of the ostio-meatal unit might reduce the oxygen pressure in the sinus, resulting in an impaired sinus clearance (Aust and Drettner 1974). This environment possibly favours growth of (pathogenic) bacteria in the maxillary sinus (reduced colonisation resistance) as was found in this study three months postoperatively. In reverse, after recovery of the sinus the environment might be comparable with the preoperative situation.

Histomorphological examination of maxillary sinus mucosal biopsies of all serially inspected and assessed patients revealed only an increase in the mean number of goblet cells and submucosal inflammatory cells at the postoperative phase. Presence of discharge was not detected endoscopically during follow-up. The increase of the number of goblet cells might be related to the fact that the postsurgical environment (mucosal injury) favours their development, or favours the differentiation of ciliated and basal cells into goblet cells (Halama et al. 1990; Norlander et al. 1992; Toskala et al. 1995; Bravetti et al. 1998; Smith et al. 2001). The number of goblet cells could also be interpreted as an adaptation reaction of the sinus mucosa which development takes several weeks.

Maxillary sinus floor elevation surgery appears to have little influence on the histological characteristics of the sinus mucosal membrane and on maxillary sinus physiology. The mild histopathological changes found probably reflect a diffuse expression of the dynamic course of the mucosal airway defence system and are of limited importance. Based on the results of this prospective study, it can be concluded that a maxillary sinus floor elevation with autogenous bone is a well-established procedure with only minimal effects on the maxillary sinus physiology not leading to manifest pathology.
Acknowledgement
Dr. A.T.M.G. Tiebosch, pathologist, is gratefully acknowledged for his help with the evaluation of the morphologic samples. Special thanks to Mr. Geert Kors, Mr. Dick Huizinga and Mr. Bert Hellings (Department of Cell Biology, section Electron Microscopy) for their technical assistance in preparing the thin sections for TEM examination of the biopsy specimens and photographic work.

References


Chapter 7

The Value of Waters’ Projection for Assessing Maxillary Sinus Inflammatory Disease

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Abstract

The significance of Waters’ projection for judging maxillary mucosal disease is, at least, questionable. The aim of this study was to evaluate the diagnostic utility of Waters’ projection of the maxillary sinus with particular regard to sinus mucosal swelling as a consistent sign of maxillary sinusitis.

Forty consecutive adult patients were referred to an ear, nose and throat surgeon for pain in the region of the paranasal sinus, recurrent mucopurulent rhinorrhea, and nasal congestion or obstruction for at least 3 months without any response to conservative treatment. Both conventional radiographs (Waters’ projection) and coronal and axial computed tomography (CT) scanning were recorded. The conventional radiographs and CT scans, all made within an hour, were blinded and assessed in random order by 2 independent well-trained observers with standard radiodiagnostic criteria for sinus mucosal swelling. Intra- and interobserver agreements were quantified by calculating Cohen’s kappa. The diagnostic significance of Waters’ projection was assessed with the CT scan images as criterion standard by calculating sensitivity and specificity, positive predictive value, likelihood ratio, and diagnostic odds ratio.

Cohen’s kappa for the intraobserver agreement of Waters’ examination was 0.96 and the intraobserver-agreement for CT scanning was 0.92. The interobserver agreement for Waters’ projection and CT scanning were 0.76 and 0.92, respectively. With CT scanning as criterion standard, the sensitivity and specificity of Water’s projections to detect maxillary sinus mucosal swelling were 83.3% and 69.2%, respectively. The positive predictive (diagnostic) value of Waters’ projections was 83.3%, the positive likelihood ratio 2.7 and the diagnostic odds ratio 11.25.

From this study it can be concluded that Waters’ projections does not necessarily rule out the presence of maxillary sinus mucosal swelling. Additional examinations may be indicated, especially in sinus clearance compromised patients.
Introduction

Maxillary sinusitis is a common sequela of infectious diseases such as the common cold or influenza. Less commonly, sinusitis may be related to a dental cause, such as a periapical pathologic condition (odontogenic sinusitis), or result from osteomeatal occlusion caused by various anatomical disturbances or chronic inflammatory disease or allergy (Melen et al. 1986). Whatever the primary cause, sinusitis is accompanied by a release of inflammatory mediators, mucopurulent hypersecretion, and, ultimately impairment of the mucociliary transport system (Chalmers-Ballantine et al. 1949; Evans et al. 1975; Yonkers 1992). Although the symptoms of sinusitis are extremely variable, the disorder is often characterized by a typical triad of symptoms, i.e. nasal congestion, rhinorrhea and headache (Yonkers 1992).

In the practice of ear, nose and throat (ENT) surgery, naso-endoscopic examination is a generally accepted procedure to support the clinical diagnosis sinusitis. Typically, a hyperemic and edematous nasal mucosa with mucopurulent discharge around the osteomeatal unit and the middle meatus is an important finding (Chalmers-Ballantine et al. 1949; Buitker 1976; Deacreton et al. 1981; Pfeilderer 1986; Druce 1992; Yonker 1992; Williams et al. 1993). For the purpose of paranasal endoscopic surgery, anatomic landmarks illustrated by computer tomography, (CT), but not by conventional radiographs, are used to support the diagnosis and assist the surgeon to prevent severe complications, such as skull base perforation and orbital haematoma (Vuorinen et al. 1962; Fascinelli et al. 1969; Wett-Boolsen et al. 1977; Decreton et al. 1981; Stammberger 1986; Kamel 1989; Wilson et al. 1990; Kennedy 1992; Zinreich 1992; Kaluskar et al. 1993; Roberts et al. 1995). This is the main reason that CT is regarded to be superior to plain radiography in this field, despite the disadvantages of the relatively high radiation-dose and cost of CT-scanning (Roberts et al. 1995).

Despite to the advantages of nasal endoscopic examination and CT, conventional radiographic examination is commonly used, especially for screening for paranasal sinus disease (Evans et al. 1975; Decreton et al. 1981; Williams et al. 1993; Chen et al. 1999). In the field of ENT surgery, conventional radiographic imaging of the paranasal sinus consists of projections in 2 planes, occipitomental (Waters’ projection, Figure 1A) and anteroposterior (Caldwell projection, Figure 1B). In oral and maxillofacial surgery, however, the radiographic examination is usually limited to Waters’ projection.

Traditionally, maxillary sinusitis is diagnosed radiographically by an air-fluid level, opacification along the sinus walls, or opacification of the entire sinus.
Opacification along the sinus walls is considered to represent mucosal thickening, although considerable disagreement with nasendoscopic findings has been reported in previous studies (Buiter 1976; Watt-Boolsen et al. 1977; Pfeiderer et al. 1986). The prevalence of mucosal thickening of the maxillary sinus in noninfected trauma patients has been assessed with conventional radiographs by Wilson in 1990. In this retrospective study, nearly 50 percent of trauma patients exhibited swelling of the maxillary sinus mucosa. However, this study addressed acute traumatic cases and the effect of time-related posttraumatic mucosal swelling was not taken into account. Assessment of maxillary sinus pathology with conventional radiographs is often subject of discussion, and, as such have been compared with other imaging techniques (MacAlister et al. 1989; Ohba et al. 1990; Von Klose et al. 1991; Larenne et al. 1992; Lazar et al. 1992; Burke et al. 1994; Katz et al. 1995; Hartog et al. 1996). Misinterpretation may easily occur, for example due to asymmetric projection, overlying soft tissues, variation in sinus depth, low pneumatization and insufficient quality of the radiograph (Wald 1983).

Conventional radiography according to Waters’ projection is also applied for routine examination of the maxillary sinus as part of the planning of surgical procedures, such as sinus floor elevation. The rationale for this strategy is that sinus floor elevation surgery may enhance an exacerbation of maxillary sinusitis in a marginally ventilated or diseased sinus (Timmenga et al. 1997). However, it is questionable whether a pre-operative radiographic assessment of the maxillary sinuses with Waters’ projection provides useful information to the oral surgeon. A localised infection in the anterior ethmoid area (containing the osteomeatal unit) may disturb the normal mucociliary clearance system of the maxillary, ethmoidal and frontal sinus. This plays an important structural role in the recurrence of sinusitis (Stammberger 1986; Kamel 1989; Kennedy 1992; Kaluskar et al. 1993). Waters’ projection does not provide information about the ethmoid area, therefore, a clear maxillary sinus on the Waters’ projection does not necessarily imply an uneventful situation. Thus, there is a risk that relevant existing pathology is missed, which might lead to unnecessary (post-surgical) complications. Conversely, a false positive outcome of the Waters’ projection might result in unnecessary diagnostics and even in treatment of non-existing pathology (Abrahams et al. 2000; Wiltfang et al. 2000). In addition, an indicated (surgical) intervention would be unnecessarily deferred. Therefore, a more comprehensive examination might be indicated in cases where the Waters’ projection appears to be insufficient.
Figure 1
Patient with a history of sinusitis.

A Projection according to Waters.
The maxillary sinus shows a normal aspect.

B Projection according to Caldwell.
Possibly some mucosal swelling is present in the ethmoidal area (arrows). This observation warrants further imaging.
Figure 1 (continued)
Patient with a history of sinusitis.
C Coronal CT-scanning at the level of the infundibular area, showing mucosal swelling of the right middle meatus (arrow). This results in obstruction of the ostio-meatal unit.
D Axial CT-scanning at the level of the anterior ethmoid area, showing mucosal swelling (arrow).
Additional radiographic examination (for example according to Caldwell, in accordance with conventional radiographic examination in ENT surgery), would be an option.

The aim of the present study was to evaluate the diagnostic value of Waters’ projection of the maxillary sinus with particular regard to sinus mucosal swelling as a consistent sign of maxillary sinusitis.

**Materials and Methods**

**Patients**

Forty consecutive patients, referred by their general practitioner to the ear, nose and throat department of the Deventer Hospital, the Netherlands, participated in this study. All patients had symptoms of pain in the region of the paranasal sinus, recurrent mucopurulent rhinorrhea and nasal congestion or obstruction for at least 3 months without any response to conservative treatment with antibiotics and decongestants during this period. The study base comprised 28 men and 12 women (mean age 46.5 years, SD 16.0 yrs). All patients had given their written consent for participation in this study.

**Study design**

The study design was cross-sectional. In all patients, the clinical diagnosis was supported by a conventional recording (the ‘predictor’ for mucosal swelling), which was compared with the outcome of a CT scan (regarded as the reference standard for mucosal swelling with regard to sinus pathologic condition (Watt-Boolsen et al. 1977; Decreton et al. 1981; Stamberger 1986; Kamel 1989; Wilson et al. 1990; Kennedy 1992; Zinreich 1992; Kaluskar et al. 1993; Roberts et al. 1995). Both radiographic examinations were carried out independently within a period of one hour.

**Radiographic procedures**

**Waters’ projection**

A Waters’ projection was made with the patient’s chin positioned against the case, the head being in a backward position. The orbitomeatal line was set at an angle of 40 degrees with the case to avoid overprojection of the maxillary sinuses by the petrosal bones, and to obtain the complete outline of the maxillary sinuses. In
addition, the mouth was opened to depict the sphenoid sinus underneath the outline of the maxilla. All radiographs were made by the same team of radiolaboratory workers, using standardized procedures.

**Computer tomography**
A third generation CT-scanner (Somatom 125 KV, Window width 1500, Level 125, Mass 140, scan-time 3 sec Siemens, Erlangen, Germany) was used. In the coronal plane, 3 mm cuts were made with 1-mm overlap. Supplementary axial slides were made of the ethmoidal area to be well informed about the area of the osteomeatal unit. All CT scans were made by a team of 2 experienced CT laboratory workers, with a standardized protocol for paranasal examination.

**Interpretation of the images**
The radiographs and CT scans were assessed separately by 2 independent experienced medical radiologists. All radiographs and CT scans were blinded before interpretation and the observers were unaware of the specific clinical background of the patients. The images were interpreted in random order with regard to maxillary sinus mucosal swelling according to generally accepted radiodiagnostic 3-point scales (Waters’ projection 0: clear sinus, 1: partial opacification, cyst, air fluid level, 2: total opacification; CT scan 0: clear sinus, 1: partial opacification, cyst, 2: total opacification) (Som et al. 1991). After one week the entire procedure was repeated.

**Data analysis**
Intraobserver and interobserver agreement was quantified by calculating Cohen’s kappa. Cohen’s kappa is a measure of agreement adjusted for agreement due to chance (Kappa = [PO-Pe]/[1-Pe], where PO is the proportion of radiographs on which the observers agreed with regard to grading, and Pe is the proportion for which agreement is expected by chance). Cohen’s kappa is interpreted in qualitative terms. A kappa of 0.60-0.80 is regarded as ‘substantial’ and a kappa greater than 0.80 reflects an ‘almost perfect’ agreement (Altman 1991).

The diagnostic significance of Waters’ projection for assessment of maxillary sinus infectious diseases was compared with the CT scan images as criterion standard. For this purpose, the results of the assessments were dichotomized (clear maxillary sinus versus mucosal swelling), and radiographs that could not be interpreted were excluded. Moreover, the percentage of patients with a clear maxillary
sinus on the Waters’ projection, who appeared to have mucosal swelling on the axial CT slides of the ethmoid, was evaluated.

The following measures were calculated:

- Sensitivity and specificity as measures of diagnostic validity. The sensitivity was defined as the proportion of cases with a positive diagnosis (according to CT) presenting mucosal swelling as assessed with Waters’ projection; the specificity was defined as the proportion of cases with a negative diagnosis (according to CT) not presenting mucosal swelling as assessed with Waters’ projection.
- The diagnostic value (positive predictive value), defined as the probability that mucosal swelling is present on CT when it is present on Waters’ projection, was calculated as a measure of diagnostic utility.
- The likelihood ratio (LR) contrasts the proportions of patients with and without mucosal swelling on CT who display the presence (LR⁺, the likelihood ratio for a positive test result) or absence (LR⁻, the likelihood ratio for a negative test result) of mucosal swelling as assessed with Waters’ projections. The diagnostic odds ratio (defined as LR⁺/LR⁻) provides a measure of the discriminatory power of assessment with Waters’ projection (Sacket et al. 1991, Sacket et al. 2000)

**Results**

**Interpretation of images**

Grading data are presented in Table 1. At the first occasion, out of the 40 conventional radiographs 5 projections could not be interpreted by observer A and 3 by observer B. Observer A judged mucosal swelling as being present (based on the CT scan reference standard) in 25 cases (62.5%), while 27 cases had mucosal swelling according to observer B (67.5%).

After correction for non-interpretable radiographs, observer A could confirm the opacifications on CT-scanning in 20 of 35 patients (corresponding with a sinusitis ‘prevalence’ of 0.57) and; observer B confirmed the presence of opacifications in 24 of 37 patients (corresponding with a prevalence of 0.65).
Agreement within and between observers

The intraobserver agreement (test-retest reliability) was comparable for both projections; it was greater than 0.80 for both observers. The between-observers reliability (interobserver agreement) yielded Kappa values greater than 0.75; thus, interpretation of Waters’ projections appeared to be adequate as far as reproducibility is concerned.

Diagnostic performance of Waters’ projection with CT as reference standard

Observer A judged sinus mucosal swelling to be present on Waters’ projections as well as on CT scans in 19 cases (true positive rate), while in 8 cases mucosal swelling was judged to be absent on both projections (true negative rate). The true positive and negative rates for observer B were 20 and 9, respectively. Five out of 13 patients (28%, observer B) with a clear maxillary sinus on Waters’ projection appeared to have mucosal swelling on the axial CT slides in the ethmoid area (Figures 1C and 1D). With CT scanning as reference standard, the test-validity parameters of Waters’ projection are summarised in Table 2.

Table 1  Grading of Waters’ projection and CT scans by both observers.

<table>
<thead>
<tr>
<th></th>
<th>Observer A</th>
<th></th>
<th>Observer B</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Occasion 1</td>
<td>Occasion 2</td>
<td>Occasion 1</td>
<td>Occasion 2</td>
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<tr>
<td>Waters CT</td>
<td>Waters CT</td>
<td>Waters CT</td>
<td>Waters CT</td>
<td>Waters CT</td>
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<tr>
<td>0</td>
<td>9 15</td>
<td>9 14</td>
<td>13 13</td>
<td>14 14</td>
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<tr>
<td>1</td>
<td>18 15</td>
<td>18 20</td>
<td>13 17</td>
<td>13 18</td>
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<tr>
<td>2</td>
<td>8 10</td>
<td>12 6</td>
<td>11 10</td>
<td>11 8</td>
</tr>
<tr>
<td>Judgement not possible</td>
<td>5 1</td>
<td>3 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0 = Clear sinus  
1 = Partial opacification, cyst, air fluid level  
2 = Total opacification

Table 2  Diagnostic performance of Waters’ projection with CT-scanning as reference standard.

<table>
<thead>
<tr>
<th>Diagnostic parameter</th>
<th>Observer A</th>
<th>Observer B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>95.0</td>
<td>83.3</td>
</tr>
<tr>
<td>Specificity</td>
<td>53.0</td>
<td>69.2</td>
</tr>
<tr>
<td>Pos. Predictive Value (PPV)</td>
<td>73.1</td>
<td>83.3</td>
</tr>
<tr>
<td>Likelihood ratio (LR+ / LR-)</td>
<td>2.02 / 0.094</td>
<td>2.7 / 0.24</td>
</tr>
<tr>
<td>Diagnostic odds ratio</td>
<td>21.5</td>
<td>11.25</td>
</tr>
</tbody>
</table>
Discussion

The present study suggests that a clear sinus on a Waters’ projection does not consistently rule out the existence of maxillary mucosal inflammatory disease. Mucosal swelling was judged to be present on CT-scanning in about 2/3 of the patients presenting with clinical signs and symptoms of sinusitis; this implies that the clinical diagnosis could not be confirmed with CT-scanning in 1/3 of the patients. It is widely recognised that clinical signs are not always associated with typical radiographic findings such as opacification. Typical structural features that may interfere with clearance and drainage need to be taken into account as well. Imaging is especially useful for detecting or ruling out sinus disease when patients do not display (all) classic signs and symptoms or do not have a history of episodes of sinusitis. This is especially important in preoperative cases, (e.g. before sinus floor elevation surgery), because of the risk of loosing a bone graft as a result of an exacerbation of pre-existing sinusitis (Timmenga et al. 1997).

Although accepted criteria for radiodiagnostic interpretation were used in this study (Som et al. 1991), comparison of a single Waters’ projection with a sequence of CT scanning slices of the same maxillary sinus may explain some of the false negative findings. If one or more of the maxillary sinus CT slices showed mucosal thickening, we scored this sinus as ‘pathological’. Conversely, in case of absence of mucosal swelling of the maxillary sinus, judgement of conventional radiographic examination may be difficult, as illustrated by the relatively large number of false positive findings. Several studies have addressed the comparison between conventional sinus radiography and CT-scanning (MacAlister et al. 1989; Ohba et al. 1990; Von Klose 1991; Larenne et al. 1992; Lazar et al. 1992; Burke et al. 1994; Katz et al. 1995; Hartog et al. 1996; Fonseca et al. 1998). The choice of CT-scanning as a reference standard in our study was mainly based on the fact that this technique is widely accepted as the standard imaging procedure before planning endonasal surgery, and that CT and conventional radiographs were performed within 1 hour. In none of previous studies the influence of time between the radiographic techniques was taken in account.

The presence of mucosal swelling based on interpretation of Waters’ projection appeared to be overestimated by observer A, whereas observer B judged mucosal swelling to be present in a slightly smaller proportion of the patients as compared with the reference standard. However, both the Waters’ projection and the reference standard were interpreted reliably by both observers.
After dichotomization of the data, interpretation of Waters’ projection differed from the reference standard in about 20% of the cases. In the majority of these misinterpretations, mucosal swelling was judged to be present while in fact this was not the case (i.e., it was a false positive judgement). This is reflected by the relatively low specificity of Waters’ projection, (i.e., a relatively small percentage of cases in which the absence of mucosal swelling was correctly assessed with Waters’ projection). The sensitivity of Waters’ projection was approximately 85%, indicating that in approximately 15% of the cases, a diagnosis of sinusitis (i.e., the clinical diagnosis supported by imaging) was missed. This implies that this proportion of patients would not receive any treatment, despite the presence of disease.

A better indicator of the power of Waters’ projection as a diagnostic tool used to confirm the actual presence of sinusitis in patients with a clinical history suggesting its presence, is the likelihood ratio (LR, Table 2). The likelihood ratio relates the pre-test probability to the post-test probability of a target disorder (Sacket et al. 1991).

For example, when the pre-test probability (based on the clinical status suggesting the presence of sinusitis) is 10%, and the positive and negative LR are 2.7 and 0.24 respectively, the probability that a patient actually has sinusitis when Waters’ projection suggests so is approximately 25%, whereas the probability of having sinusitis is 2% when Waters’ projection does not show any signs of the disease. On the basis of the data of the present study, probability of mucosal swelling according to observer B is 65%, which increased to 83% by performing a Waters’ projection.

In addition to its reliability (test-retest reliability and inter-observer reliability) and validity, one must address the practical feasibility of a diagnostic tool to judge its clinical significance. With respect to its feasibility, Waters’ projection has several important advantages over other diagnostic tests. The method is relatively cheap and can be easily performed within a few minutes. It has a relatively low radiation dose (Lazar et al. 1992). The aspect of applicability of conventional radiography should certainly be taken into account when deciding which diagnostic instruments should be used in particular clinical situations.

From a methodological perspective, one could prefer to include a nonsymptomatic control group in this study. However, such a control group is not a prerequisite given the aim of our study. Because ethical arguments (high radiation dose on the eyes of healthy humans from CT scans) do not support the inclusion of a negative control group, we decided not to do so.
To cover processes in the ethmoid area, additional imaging of this area might be indicated. In these cases, we recommend evaluating patients preoperatively with serial conventional radiography according to Waters’ and Caldwell’s projections, in accordance with common practice in ENT surgery. In case of an increased risk of developing sinusitis (suggested by the presence of anamnestic clearance-related factors, and/or by the presence of mucosal swelling on serial conventional radiography), CT scanning or nasendoscopy is indicated to rule out structural drainage problems of the paranasal sinus.

From this study it can be concluded that Waters’ projections does not reliably rule out the presence of maxillary sinus mucosal swelling. Therefore, when false positive or false negative findings have serious consequences, one should certainly consider additional examinations, e.g. Caldwell’s projection, CT-scanning and/or nasendoscopy.

**References**


Chapter 8

General Discussion
Introduction

Currently, sinus floor elevation surgery with autogenous bone grafts and/or bone substitutes is a generally accepted surgical procedure that enables reliable implant insertion (Raghoebar et al. 1997, 2001). There is, however, still discussion in the literature regarding such a procedure, particularly regarding the morbidity of this procedure and the maxillary sinus performance post-elevation (Bhattacharyya 1999; Doud Galli et al. 2001). The most frequently reported complication of this procedure is the development of maxillary sinusitis (Timmenga et al. 1997, 2001, 2002). Post-elevation maxillary sinusitis has been reported to develop in up to 26% of the cases, fortunately usually as a temporary condition that can be adequately treated. Especially with regard to a better understanding of potential effects of the elevation procedure on maxillary sinus performance and their possible treatment, it is interesting to gain more insight in the effects of this procedure on the morphology and function of the antral mucosa and the maxillary sinus physiology. The main research outcomes of the various chapters of this thesis are discussed in a broader perspective in this general discussion.

Effects on the antral mucosa

Post-elevation, morphological examination showed that no significant changes were apparent in the antral epithelium and submucosa. At most, there was a tendency towards an increase of the goblet cell-ratio. One third of the patients showed thickening of the basal lamina. The mild inflammatory mucosal reaction that occurred post-operatively was not different from the responses that can be observed in the maxillary sinus of healthy individuals not having been exposed to maxillary sinus surgery. Therefore, this mild inflammatory reaction must be considered as a sign of the normal physiologic activity of the mucosal airway defence system (Kauffman and Tomee 1997). Thus, the outcomes of our morphologic studies strongly support the hypothesis that the maxillary sinus mucosa is capable of adapting adequately to the changes induced by a sinus floor elevation procedure (Timmenga et al. 2002).
Effects on sinus physiology

Elevation of the floor of the maxillary sinus with autogenous bone grafts and/or bone substitutes will result in an altered maxillary sinus environment, at least in a reduction of the volume of the maxillary sinus. Consequently, vascular injury following surgery, mucosal swelling, stasis of old blood, and a decreased patency of the ostio-meatal unit all might be of influence on the oxygen pressure in the sinus. Theoretically, reduction of the oxygen pressure might result in a temporarily impaired sinus clearance, affecting the mucosal defence system (Aust and Drettner 1978; McGowan et al. 1993).

The results of this study have shown that temporary clearance impairment in preoperatively healthy patients result in only (sub)-clinical effects on maxillary sinus physiology. In case of pre-operative sinus clearance disturbances, sinus floor elevation surgery may provoke exacerbations of sinusitis. Sinus drainage obstructing phenomena might be aggravated by inflammation, when associated with a sinus floor elevation procedure (Timmenga et al. 1997). Another possible effect of the elevation procedure on the clearance of the maxillary sinus might be its influence on the microbial environment. An elevation procedure might result in an outgrowth of (potentially) pathogenic micro-organisms or the introduction of micro-organisms that are not part of the commensal flora of the maxillary sinus. Our study showed a significant increase in positive sinus culture results three months post-elevation when compared with the pre-operative results. These three-months post-elevation cultures showed a low growth density of mostly low pathogenic micro-organisms. A clinical implication related to the increase of culture results was not found (Timmenga et al. 2002). Nine months post-elevation, culture results were comparable with the culture results that were found pre-elevation. The current opinion about the microbiologic colonisation of the maxillary sinus is that this cavity is not sterile (Hartog 1997). Therefore, in our opinion, bacterial growth induced by sinus floor elevation, in the absence of clinical symptoms does not appear to be of significant relevance. Post-operatively, an environment was created in the sinus that temporarily favoured and/or diminished the clearance mechanism of the maxillary sinus. This effect was fully recovered at the nine months’ evaluation. For clearance compromised patients, the temporary negative effect on maxillary sinus clearance might favour the development of post-elevation sinusitis.
Patient related factors

In this study, only patients without actual clinical and radiographic signs of sinusitis were included. Patients with a history of a disturbed clearance function of the maxillary sinus were included only in case of absence of preoperative clinical and radiographic signs of actual sinusitis. In case of other medical compromising factors, e.g. diabetes mellitus, internal screening and regulation were performed pre-operatively. With respect to anamnestic pre-disposing sinus clearance disturbing factors, two subgroups of patients were distinguished in this study. It was shown that post-elevation maxillary sinusitis more frequently developed in patients with pre-disposing factors for maxillary sinusitis than in patients without pre-disposing factors (Timmenga et al. 1997). Thus, even if such patients do not have actual clinical or radiographic signs of sinusitis, further pre-surgery ENT screening should be considered in this subset of patients. Consequently, in case of structural clearance disturbance, ENT interventional surgery might be indicated before the elevation procedure can be performed, even if the patient is clinically symptom free.

The potential effects of ageing and smoking on morbidity of the elevation procedure and graft survival are unknown. They were not subjects of evaluation. These aspects should be included in further studies. Apart from negative effects of tobacco smoking on the human organism in general, effects on sinus clearance and the bone graft might be expected as well (Jensen et al. 1998; Wallace 2000). With respect to ageing, diminished maxillary vascularisation, in older edentulous patients, might be affecting the elevation procedure as well (Staudt et al. 1977; Solar et al. 1999; Traxler et al. 1999).

Factors related to surgery

Sinus floor grafting is thought to be a technique-sensitive procedure (Jensen et al. 1998). The experience of the surgeon, elevation and graft fixation technique, the occurrence of sinus membrane perforations, contamination during surgery and wound closure are thought to be factors related to surgery with clinical implications for the development of post-operative complications.

During surgery, delicate tissue handling is mandatory, in particular to preventing (vascular) damage of the vulnerable Schneiderian membrane. Accidental perforations of the sinus membrane may occur as a result of the elevation proce-
dure. It has been assumed that shedding of bone particles via the perforation into the maxillary sinus may be a possible cause of post-elevation maxillary sinusitis (Raghoebear et al. 2001). Therefore, there is a need for proper techniques to close such perforations during surgery, especially since such perforations are not exceptional occurrences. Placement of cortical bone just below the perforation has been shown to be an appropriate technique to seal such perforations. Raghoebear et al. (2001) reported that no relationship between membrane perforations and the development of maxillary sinusitis was present when using such a technique, although in 30% of their patients a (minor) preoperative perforation was observed. Other techniques used for closing (large) membrane perforations include the use of collagen (Block and Kent 1998; Picos 1999), fibrin adhesive (Sullivan et al. 1997), and suturing (Raghoebear et al. 2001).

With regard to the elevation procedure, the graft should be shaped to fit the antral floor. Delayed graft incorporation might be expected when the sinus is overfilled and/or in old edentulous patients due to limited maxillary vascular supply. Successful incorporation and survival of the bone graft requires adequate infiltration of the graft mass by endothelial cells (Chen et al. 1994; Wong 2000). Therefore, comparable to fracture healing, stability of the graft is thought to be important (Bruder et al. 1994; Raghoebear et al. 1997).

Contamination of the sinus or bone graft during sinus floor elevation surgery is likely to occur. This contamination, however, does not result in clinical complications in many cases (Misch 1992). It should be mentioned, that shifts in antral microbiology, as were found in our study, showed to be temporary, and obviously without clinical consequences. The explanation for this is not known. Preoperative administration of antibiotics and adequate wound closing possibly might play a role in preventing such post-operative complications.

To prevent wound dehiscence, and protracted contamination from the oral cavity, the muco-periosteal flaps should be closed tensionless, but watertight, at the end of the surgical procedure. In cases in which a wound-dehiscence, wound infection or fistula developed, maxillary sinusitis did not occur, however. A possible explanation might be that the maxillary sinus mucosa in immunological homeostasis has an innate effective defence system, and a high regenerative capacity and thus will quickly return to normal once the sinus regains its adequate ventilation and drainage (Stammberger 1989; Jensen et al. 1998). Another explanation might be that a relationship between oral soft tissue reactions and sinusitis did not exist.
Consequences

Maxillary sinusitis, either transient or chronic, is the most widely reported complication that may develop after elevation of the maxillary sinus floor with autogenous bone and/or bone substitutes. According to the commonly accepted ENT definition for sinusitis (Yonkers 1992) this disorder is suspected to be present in a patient complaining of headache, pain or tenderness in the region of the maxillary sinus, in combination with rhinorrhea, and postnasal drip. Conventional radiographic examination (e.g. according to Waters’ projection) might show a sharp boundary between a radiopaque and radiolucent area (suggestive of an air-fluid level), or an opaque lining of the maxillary sinus suggestive of a thickening of the maxillary sinus mucosa. In case of transient sinusitis, the duration of complaints is 6-8 weeks at most. Absence of purulent discharge supports this diagnosis. Chronic sinusitis has a duration of at least 8 weeks. The endoscopic presence of polypoid sinus mucosal thickening often supports the diagnosis of chronic sinusitis. Although it was shown that post-elevation transient sinusitis more frequently develops in patients with pre-disposing factors for maxillary sinusitis than in patients without pre-disposing factors (Timmenga et al. 1997), this finding does not have any clinical implications as its treatment is rather simple and effective. Chronic sinusitis, however, may need ENT-intervention, to improve sinus clearance structurally.

As already mentioned, there is no consensus in the literature regarding the percentage in which maxillary sinusitis will develop following an elevation procedure, which varies from 0 to 26%. The discrepancy between the reported percentages might be due to the wide variety of criteria and methods (i.e. clinical, radiographic and/or endoscopic) used for diagnosing maxillary sinusitis, the surgical procedure applied, and patient related factors. In many previous reports, the occurrence of accidental perforations of the sinus membrane was mentioned as an important reason for the development of post-elevation maxillary sinusitis. In our study in approximately 30% of the patients the membranous lining had been perforated, and using the ‘cortical bone plating technique’, development of post-elevation maxillary sinusitis did not appear to be related to sinus membrane perforations (Raghoobair et al. 1997, 2001; Timmenga et al. 1997). A possible explanation for development of chronic maxillary sinusitis in our study might be that, despite careful inspection, accidental perforations were not detected, or that the cortical bone plating technique was not performed successfully.
**Prevention of post-elevation maxillary sinus pathology**

Pre-operative screening on pre-existent sinus clearance impairment should be performed. Using anamnestic, clinical and radiographic examination, predisposing sinus clearance disturbances may be distinguished. In case of structural clearance disturbances patients should be referred to the ENT-department. ENT-surgery might be indicated pre-elevation to improve sinus ventilation and/or clearance e.g. in case of polyposis in the infundibular area, obstructing the ostio-meatal unit.

With regard to the pre- and peri-surgical condition, antibiotics should be administered to prevent sinusitis, starting one hour pre-operatively and to be continued for at least 48 hours. Only a short-lived effect of antibiotic treatment on the (vascureal) inserted graft might be expected, preventing inflammation of the graft (Kucers et al. 1997). Preventing inflammation of surrounding soft tissue probably plays a role as well (Laskin et al. 2000). A pre-operative mouthwash with chlorhexidine 0.12% might reduce oral contamination (Young et al. 2002). However, it should be mentioned that the effect of mouthwashes, in preventing post-operative complications following oral surgery, is questionable. Decongestants should be prescribed post-elevation to improve the patency of the ostio-meatal unit. Systemic and topical corticosteroids are thought to be important additional medication for reduction of post-operative swelling.

**Treatment of post-elevation maxillary sinus pathology**

Despite thorough pre-operative patient evaluation and sinusitis preventing measures, post-elevation maxillary sinusitis still might occur as a post-operative surgical complication.

In case of transient sinusitis, decongestants, and antibiotics have to be administered for two weeks. Clinical examination and conventional radiography (Waters’ projection) usually will show complete recovery.

In case of chronic maxillary sinusitis, ENT-intervention is indicated. Additional examination (CT-scanning, antroscopy) might be necessary. Sinus lavage will be performed, and depending the culture results, the patient needs antibiotics. When present, antral sequestrums should be removed and functional sinus surgery (e.g. nasal antrostomy and/or anterior ethmoidectomy should be performed. When the appropriate measures for sinus recovery are taken, the compromised
sinus will regain its ventilation and clearance. These procedures are thought to be required to support the preservation of the bone graft.

**Future research**

Although the results of this thesis suggest that the incidence of post-elevation maxillary sinusitis is rather low, development of post-elevation maxillary sinusitis still might occur and puts forward many unanswered questions. In particular, when treating patients with structural pre-operative clearance disturbances (e.g. post-radiation therapy, or at the presence of sicca-syndrome) future research is needed for development of protocols, and guidelines, to perform sinus floor elevation surgery in sinus clearance compromised patients successfully.

**References**


Chapter 9

Summary
In edentulous patients, the continuing process of resorption of the maxilla, related to loss of teeth in the upper jaw, may eventually result in poor denture retention. When this problem can not be solved by prosthetic improvement, additional procedures, such as insertion of endosseous implants to support the prosthetic construction, are needed. However, reliable insertion of endosseous implants in the maxilla is often complicated by insufficient height and width of the alveolar process. In such cases, reconstructive preprosthetic surgery is necessary before implants can be inserted reliably at preferred sites.

A common procedure aimed at establishing an adequate environment for the insertion of endosseous implants is elevation of the maxillary sinus floor with autogenous bone and/or bone substitutes. Although sinus floor elevation a commonly used surgical procedure in the field of reconstructive maxillofacial surgery, the effects of such a procedure on maxillary sinus physiology are unknown. In the literature, post-elevation maxillary sinusitis has been reported to occur in 13.8% on the average (standard deviation 9.4%). When this complication occurs, the inserted bone graft might be at risk. The aim of this study was to investigate the course, prevention and treatment of post-maxillary sinus elevation morbidity. Special attention was paid to the occurrence of maxillary sinusitis in a group of patients without pre-operative symptoms or clinical and radiological signs of maxillary sinusitis.

In addition to the above mentioned topics, a brief general introduction to some anatomic and physiologic aspects of the maxillary sinus, relevant for maxillary sinus floor elevation with iliac crest bone grafts, is provided in chapter 1.

In chapter 2, the long-term clinical and radiographic outcomes, with regard to the graft, the implant survival and patient satisfaction with their implant-supported overdentures were studied retrospectively in 99 patients. The sinus floor was elevated with bone grafts derived from the iliac crest (n=83), the mandibular symphysis (n=14) or maxillary tuberosity (n=2). The width and height of the alveolar crest had to be increased in a first stage procedure in 74 patients, while in the other 25 patients elevation and implant insertion could be performed simultaneously (width and height of the alveolar crest > 5 mm) because in the latter cases sufficient primary implant stability could be obtained during first stage surgery.

Perforation of the maxillary sinus membrane occurred in 26% of the cases. Perforations did not predispose to the development of sinusitis. Loss of bone particles and sequestration were observed in one (diabetic) patient only. In this patient a dehiscence of the oral mucosa occurred. A second elevation procedure
was necessary in this patient. Symptoms of transient sinusitis were observed in three patients (3%). These symptoms were successfully treated with decongestants and antibiotics. Two other patients (2%) developed a purulent sinusitis, which resolved after a nasal antrostomy. Thus, post-elevation maxillary sinusitis occurred in 5% of the patients in this study, which is lower than generally assumed in the literature (13.8±9.4%).

In all cases, the bone volume was sufficient for implant insertion. Thirty-two of the 392 inserted Bränemark implants (8.2%) were lost during the follow-up. No sinus pathology was observed after insertion of the implants. The patients received implant-supported overdentures (n=72) or fixed bridges (n=27). All in all, the patients were very satisfied with the prosthetic construction.

From this study it is concluded that sinus floor elevation surgery with autogenous bone grafts is a reliable procedure if properly planned and performed. It has been shown to result in good overall denture satisfaction of patients. The procedure is not without complications, however, and the surgeon must be able to manage problems that arise preoperatively as well as those that develop in the early and late postoperative phases.

Chapter 3 describes a retrospective study on the development of maxillary sinus pathology following sinus floor elevation surgery with autogenous bone grafts. Assessment of post-elevation sinusitis was performed according to generally accepted diagnostic ENT-criteria. Evaluation was performed 12 to 60 months after the surgical procedure, using a questionnaire on sinus clearance related factors, conventional radiographic examination according to Waters, and nasendoscopy. In total 45 patients were evaluated.

Postoperative maxillary sinusitis had developed in two out of the five patients with a predisposition for sinusitis and in none of the other 40 patients. The occurrence of iatrogenic sinus membrane perforations during the elevation procedure was not found to be related to the development of post-operative sinusitis in patients with healthy sinuses.

From this retrospective study it was concluded that elevation of the maxillary sinus floor by autogenous bone grafting in patients without anamnestic or radiographic evidence of pathologic disease does not induce sinusitis. In these cases performance of nasendoscopy does not seem to be necessary. Furthermore, it was stated that a prospective study has to be performed on the value of preoperative nasendoscopic examination in patients with a history of sinus clearance impair-
ment factors who need elevation surgery of the maxillary sinus floor before recommending preoperative nasendoscopy for all such patients.

In chapter 4, the two out of 156 patients (i.e., 1.5%) that developed chronic sinusitis following sinus elevation surgery were described. These patients were among the patients who had been treated between 1988 and 1998 with bilateral sinus floor elevation with autogenous bone grafts. Both patients needed functional endoscopic sinus surgery to establish adequate drainage of the maxillary sinus to recover, and to prevent loss of the inserted bone graft. In addition, transient sinusitis had developed in seven patients (4%). The possible relationship between pre-operative sinus clearance disturbances and development of post-elevation maxillary sinusitis was discussed. General guidelines for the treatment of transient and chronic maxillary sinusitis after sinus floor elevation surgery were given.

The effects of maxillary sinus floor elevation surgery on maxillary sinus performance were prospectively studied in a group of 17 consecutive patients who needed maxillary sinus floor elevation surgery with iliac crest bone grafts. The patients had no pre-operative anamnestic, clinical or radiographic signs of actual sinus pathology. All patients were subject to extensive anamnestic and clinical investigation on sinusitis, conventional radiography (Waters’ projection) and unilateral endoscopic inspection of the maxillary sinus mucosa and ostio-meatal unit. This triad of evaluations was performed preoperatively, immediately preceding the elevation procedure (the maxillary sinus to be inspected endoscopically was randomly assigned prior to the study), and three (at insertion of the implants) and nine (at uncovering of the implants) months post-elevation. In addition, biopsies of the maxillary sinus mucosa and a sinus lavage-fluid aspirate were collected immediately pre-elevation surgery and at the three and nine months’ evaluations.

In chapter 5 the results of the clinical and radiographic investigations, and the endoscopic examination are described. Five out of 17 patients had a history of an impeded sinus clearance, but did not show any clinical or radiological signs of actual sinus pathology preoperatively. Nor did the other 12 patients. By contrast, unilateral endoscopic elevation revealed pre-existing subclinical mucosal pathology in two out of five patients with a history of sinus clearance impairment and in one out of the other 12 patients. Three months post-elevation, clinical and radiographical examination showed chronic maxillary sinusitis in one non-compromised patient. Moreover, serial unilateral endoscopic evaluations revealed subclinical maxillary mucosal pathology in four other patients (two had a history
of an impeded sinus clearance), confirmed by Waters’ projection in three of these four patients. Nine months post-elevation, only subclinical maxillary mucosal pathology was detected endoscopically in two patients (one compromised, one non-compromised patient), confirmed by Waters’ projection in this last patient. Five implants (5.9%) were lost during the nine months’ observation period.

In chapter 6, the microbiological and morphological data are presented. The three months’ microbiological evaluation showed a significant increase of cultures with bacterial growth, while the nine months’ culture results were comparable to the preoperative status of the maxillary sinus. Morphologically, neither fibrosis nor an altered inflammatory response or thickening of the epithelium and lamina propria was observed postoperatively. The number of goblet cells in the epithelial layer was increased.

From these investigations it was concluded that the effect of maxillary sinus floor elevation surgery with autogenous bone grafts showed to be of a temporary nature and did not appear to have clinical consequences in patients without signs of pre-existing maxillary sinusitis.

Chapter 7 deals with the value of conventional radiography according to Waters’ projection for assessing maxillary sinus inflammatory disease, which according to the literature is at least questionable. Therefore, the aim of this study was to evaluate the diagnostic validity and utility of Waters’ projection of the maxillary sinus with particular regard to sinus mucosal swelling as a consistent sign of maxillary sinusitis.

In a retrospective study, 40 patients with symptoms of pain in the region of the paranasal sinus, recurrent rhinorrhea and nasal congestion were evaluated. These patients had had these signs of maxillary sinusitis for at least three months and had not responded to conservative treatment. Conventional radiographs according to Waters and coronal and axial CT-scans were made in all patients within an hour. The recordings were subsequently blinded and assessed in a random order by two independent well-trained observers with standard radiodiagnostic criteria for sinus mucosal swelling. Intra- and interobserver agreement was quantified by calculating Cohen’s kappa. The diagnostic significance of Waters’ projection was assessed with the CT scan images as reference standard by calculating sensitivity and specificity, positive predictive value, likelihood ratio, and diagnostic odds ratio.
Cohen’s kappa for the intraobserver agreement was 0.96 for Waters’ examination and 0.92 for CT scanning. The interobserver agreement for Waters’ projection and CT scanning were 0.76 and 0.92, respectively. With CT scanning as reference standard, the sensitivity and specificity of Waters’ projections to detect maxillary sinus mucosa swelling were 83.3% and 69.2%, respectively. The positive predictive (diagnostic) value of Waters’ projections was 83.3%, the positive likelihood ratio 2.7 and the diagnostic odds ratio 11.25.

From this study it was concluded that Waters’ projections did not reliably rule out the presence of maxillary sinus mucosal swelling. Therefore, when false positive or false negative findings have serious consequences, one should certainly consider additional examinations, e.g. Caldwell’s projection or CT-scanning and/or nasendoscopy.

The general discussion of this thesis is described in chapter 8 and deals with the temporary changes of the maxillary sinus physiology, as might be expected post-elevation in patients without pre-operative sinus clearance related factors. The aspects of these changes and the consequences for sinus physiology and for the lifted antral mucosa in particular are discussed in this chapter.

With regard to the mild inflammatory response of the antral mucosa that occurred post-operatively, this response was not different from the responses that can be observed in the maxillary sinus of healthy individuals not having been exposed to maxillary sinus surgery. Therefore, it should be considered as a sign of the normal physiologic activity of the mucosal airway defence system rather than as a sign of pathology. In other words, in the majority of the healthy subjects sinus floor elevation surgery results at most in a temporary clearance impairment of the maxillary sinus and mostly the resulting signs are subclinical. On the other hand, subjects with a history of sinus clearance disturbing factors, although they show no signs of sinus pathology at the time of sinus floor elevation surgery, run a much higher risk of developing sinus pathology post surgery. In these subjects, pre-operative screening can be worthwhile. If in such a subject screening shows a structural clearance disturbance, surgical intervention might be needed before sinus floor elevation surgery is performed even if there are no actual signs of sinus pathology.

With regard to the surgical procedure, grafting of the floor of the maxillary sinus with autogenous bone grafts or bone substitutes is thought to be a technique-sensitive procedure. Therefore, it is generally assumed that there is an inherent risk of increased post-operative complications in case of iatrogenic perfora-
tions of the membrane of the maxillary sinus, inadequate graft fixation, contamination of the maxillary sinus with micro-organisms during surgery, and poor wound closure. As is obvious from the results of this study, there is no higher risk of developing maxillary sinusitis post-surgery if the perforations are handled with care during surgery, e.g. by placing a cortical bone plate just below the perforations.

Finally, guidelines are provided for the prevention and treatment of post-elevation maxillary sinus pathology.
Chapter 10

Samenvatting
Het voortschrijden van resorptie van het kaakbot kan het prothesedragende oppervlak dusdanig verkleinen dat vermindering van retentie en stabiliteit van een onderprothese leidt tot klachten. Analoog hiervan kan een sterke resorptie van de bovenkaak ook resulteren in slechterhouvast van de bovenprothese. Andere oorzaken hiervoor zijn een extreme kokhalzreflex en de intolerantie van de patiënt voor in het bijzonder de gehemelteplaats van een bovenprothese. Wanneer de technische mogelijkheden om een conventionele bovenprothese te vervaardigen die voldoende retentie heeft c.q. door de patiënt in zijn of haar mond wordt geaccepteerd ontoereikend zijn, kan de vervaardiging van een overkappingsprothese of een vaste brugconstructie op implantaten uitkomst bieden. Een voorwaarde hiervoor is dat nog voldoende botvolume aanwezig is om de implantaten met een betrouwbare prognose op de gewenste posities te kunnen plaatsen.

In tegenstelling tot in het interforaminale gebied van de onderkaak is het botvolume in de edentate bovenkaak, zowel in het front als in de zijdelingse delen, vaak ontoereikend om implantaten met voldoende betrouwbaarheid te plaatsen. Dit is niet alleen het gevolg van een voortgeschreden resorptieproces, zoals vaak in de onderkaak het geval is, maar hangt vooral samen met de vaak sterke pneumatisatie van de sinus maxillaris. Daarom is het nodig om de bovenkaak te reconstrueren voordat implantaten kunnen worden geplaatst door het botvolume in de gewenste gebieden te vermeerderen. In de literatuur wordt een aantal methoden beschreven om het botvolume te vergroten, zoals het aanbrengen van autolog bot op de processus alveolaris (de zogenaamde onlay graft), een Le Fort I osteotomie met interpositie van autolog bot en de elevatie van de bodem van de sinus maxillaris met bot en/of botsubstituten.

In Nederland wordt vaak een augmentatietechniek toegepast, waarbij de bodem van de sinus maxillaris wordt verhoogd. Het effect van een dergelijke techniek op de fysiologie van de sinus maxillaris is echter nog grotendeels onbekend. Postoperatieve sinusitis maxillaris zou, zoals uit literatuuronderzoek naar voren kwam, zich in gemiddeld 13,8% (standaard deviatie 9,4%) van de patiënten ontwikkelen. Een niet goed behandelde of therapie-resistente sinusitis maxillaris na een sinusbodemeleveratie kan leiden tot verlies van het aangebrachte bot en/of botsubsstituent. Het doel van de studie die in dit proefschrift is beschreven was het prospectief evalueren van effecten van de elevatie van de sinusbodem met een bottransplantaat uit de crista iliaca anterior op de ‘performance’ van de sinus maxillaris (kliniek, histologie, microbiologie) in een groep patiënten die preoperatief zowel anamnestisch als bij klinisch en conventioneel radiologisch onderzoek (radiologisch onderzoek volgens Waters) geen aanwijzingen hadden voor een pre-
existentie sinusitis maxillaris. Algemeen geaccepteerde criteria, zoals gehanteerd in de KNO-heelkunde, vormden de basis voor het selecteren en evalueren van de patiëntengroep.

De bovengenoemde aspecten staan beschreven in hoofdstuk 1. Tevens wordt in dit hoofdstuk een korte introductie gegeven over anatomische en fysiologische aspecten van de sinus maxillaris die van belang zijn voor een beter begrip van eventuele gevolgen van een elevatie van de bodem van de sinus maxillaris met autoloog bot.

In hoofdstuk 2 wordt een retrospectieve studie beschreven waarin de klinische en röntgenologische effecten van de sinusbodem-elevatie op de lange termijn worden beschreven in een groep van 99 patiënten met retentieproblematiek van de bovenprothese. De bodem van de sinus maxillaris was geëleverd met autoloog bot uit de crista iliaca (n=83), de symphysis mandibulae (n=14) en het tuber maxillare (n=2). Bij 25 van de 99 patiënten werd de elevatieprocedure gecombineerd met het aanbrengen van implantaten, aangezien de bothoogte en botbreedte bij deze patiënten meer dan vijf mm bedroegen, waarbij een goede primaire stabiliteit van de implantaten kan worden verkregen. Bij de overige 74 patiënten, bij wie de bothoogte en -breedte minder dan vijf mm bedroegen, werd eerst alleen een elevatieprocedure uitgevoerd welke drie maanden later werd gevolgd door het plaatsen van de implantaten.

Tijdens de elevatieprocedure ontstond in 26% van de gevallen een perforatie van de membraan van de sinus maxillaris. De aanwezigheid van een dergelijke perforatie bleek, mits deze peroperatief werd afgedicht, niet te predisponeren voor sinusitis maxillaris. Verlies van bot dat een tweede elevatieprocedure nodig maakte trad bij slechts één patiënt op. Bij deze patiënt, een patiënt met diabetes mellitus, ontstond post-operatief een dehiscence van de orale mucosa alsook sequestratie van een deel van het aangebrachte bot. Bij de overige patiënten was op het moment van implanteren slechts sprake van een geringe resorptie van het aangebrachte bot.

Drie patiënten (3%) ontwikkelden symptomen die passen bij een passagère sinusitis. Met behulp van decongestiva en antibiotica konden deze symptomen met succes worden bestreden. Twee andere patiënten (2%) ontwikkelden een purulente sinusitis maxillaris. In beide gevallen was het aanbrengen van een onderste neugang antrostomie met sinusdrains en daarbij behorende frequentie spoelingen van de sinus maxillaris effectief. Na de inhelingsfase van het aangebrachte bot (drie maanden postoperatief) ontwikkelden zich geen nieuwe gevallen van sinusitis maxillaris. Met andere woorden: in slechts 5% van de patiënten die in het Acade-
Hofstuk 3 bespreekt een retrospectieve studie waarin het voorkomen van sinusitis maxillaris na elektive sinus maxillaris bleek het geëxperimenteerde botvoldoende te zijn om de gewenste postie van de 92 aangebrachte Botmark implantaten aan te brengen. Tijdens de follow-up perioden van 32 van de 92 patiënten werd een overkopingsprothese op de de bovenkaak aangebracht.

Postoperatief bleek sinusitis maxillaris zich ontwikkeld te hebben bij twee patiënten. Deze patiënten behorden tot de vier patiënten met een predispositie voor sinusitis maxillaris. Isotone perforaties van de membraan van de sinus maxillaris bleken niet de directe oorzaak van de ontslag van sinusitis maxillaris.

De resultaten van deze studie laten zien dat het onzekerheid is dat zich een sinusitis maxillaris ontwikkelde tijdens de sinus maxillaris bleek het geëxperimenteerde botvoldoende te zijn om de gewenste postie van de 92 aangebrachte Botmark implantaten aan te brengen. Tijdens de follow-up perioden van 32 van de 92 patiënten werd een overkopingsprothese op de de bovenkaak aangebracht.

Uit deze retrospectieve studie komt naar voren dat een vaste bouwbare aangebrachte implantaat met een autolog bottenplantaat hadden ondergaan, ontwikkelde zich postoperatief een sinusitis maxillaris. Dit percentage van 3% (± 1.5%) is vergelijkbaar met de 1% (± 0.1%) van de literature. Dit persentage stelt gunstig af bij het percentage die is geporteerd in de literatuur (13% ± 9.4%).

Bij alle patiënten in geval van de patiënt met diabetes mellitus na de tweede periode zette de botvorming nog steeds vertraging ondergaan. De patienten bleken zeer tevreden met hun prothese of brugbrander. De patiënten bleken zeer tevreden met hun brug of prothese.
anamnestische, klinische of röntgenologische aanwijzingen voor een verstoring van de drainage van de sinus maxillaris, lijkt preoperatief een dergelijk screenend onderzoek geïndiceerd te zijn. Deze hypothese dient echter nog in een prospectief onderzoek geverifieerd te worden alvorens deze als een algemene aanbeveling te beschouwen.

In hoofdstuk 4 worden de ziektegeschiedenis en het beloop van postoperatieve chronische sinusitis maxillaris beschreven aan de hand van de twee patiënten die deze complicatie na de sinusbodemlelvatie-procedure hebben ontwikkeld. Deze patiënten behoren tot de groep van 156 patiënten bij wie tussen 1988 en 1998 bilateraal een elevatie van de bodem van de sinus maxillaris met autolog cavot werd uitgevoerd. Deze twee patiënten had zich een purulente sinusitis ontwikkeld en moesten functionele endoscopische sinusergurgery ondergaan om de drainage van de sinus maxillaris te herstellen en te voorkomen dat het aangebrachte bot verloren ging. De mogelijke samenhang tussen een preoperatieve verstoring van de sinusdrainage en het ontstaan van sinusitis maxillaris na elevatie van de bodem van de sinus maxillaris met autolog cavot wordt uitvoerig bediscussieerd. Tevens worden richtlijnen gegeven voor de behandeling van zowel passagère als chronische sinusitis maxillaris bij patiënten die deze procedure hebben ondergaan.

De effecten op de fysiologie van de sinus maxillaris van elevatie van de bodem daarvan werden prospectief onderzocht in een groep van 17 patiënten bij wie het plaatsen van implantaten noodzakelijk was in verband met retentieproblemen van de bovenprothese. Bij alle patiënten werd bilateraal een sinusbodemlelvatie uitgevoerd met een bottransplantaat uit de crista iliaca anterior. Preoperatieve beoordeling en postoperatieve evaluatie bestond uit (a) een uitgebreide anamnese en een klinisch onderzoek gericht op de eventuele aanwezigheid van klachten en kenmerken van sinusitis, (b) een röntgenopname volgens Waters en (c) een unilaterale endoscopische beoordeling van de ostio-meatale unit en de mucosa van de sinus maxillaris. Deze laatste beoordeling werd voorafgaand aan de elevatieprocedure onder algehele anesthesie uitgevoerd. Postoperatieve evaluatie vond plaats na drie maanden (direct voorafgaande aan het aanbrengen van de implantaten) en na negen maanden (direct voorafgaande aan het vrijleggen van de implantaten) uitgevoerd. Welke sinus maxillaris endoscopisch werd beoordeeld was voorafgaand aan het onderzoek at random bepaald. Op de verschillende evaluatiemomenten werd dezelfde sinus geïnspecteerd. Tijdens de endoscopische procedure werd een sinuspoelsel voor microbiologisch onderzoek genomen en de sinus mucosa uit de re-
gio die het aangebrachte bot zou gaan bedekken (t=0 maanden) of bedekte (t=3 en 9 maanden) gebiopteerd ten behoeve van histomorfologisch onderzoek.


De microbiologische en morfologische gegevens worden beschreven in hoofdstuk 6. Drie maanden na de sinusbodemleveatie toonde microbiologisch onderzoek een significant groter aantal bacteriën in de sinus maxillaris, terwijl de resultaten negen maanden na de sinusbodemleveatie vergelijkbaar waren met die van de preoperatieve kweken. Het verrichtte morfologische onderzoek toonde postoperatief geen aanwijzingen voor ontsteking, fibrosering of verdikking van het epitheel of de lamina propria. De enige significante verandering was de toename van het aantal slijmbekercellen in het bekledende epitheel van de sinus maxillaris.
Uit het prospectieve onderzoek komt naar voren dat elevatie van de bodem van de sinus maxillaris met een bottransplantaat uit de crista iliaca, bij patiënten die preoperatief geen klachten hebben van sinusitis maxillaris, slechts tot tijdelijke en veelal subklinische veranderingen in de sinusflora en het bekledende sinus slijmvlies leidt.

Hoofdstuk 7 beschrijft een retrospectieve studie waarin de diagnostische waarde van conventioneel röntgenologisch onderzoek volgens Waters wordt onderzocht. Nagegaan wordt of dit onderzoek geschikt is om zwelling van het slijmvlies van de sinus maxillaris te diagnosticeren. Retrospectief werden 40 patiënten met minimaal drie maanden bestaande paranasale pijn in combinatie met obstructie van de neus en rhinorrhoe en bij wie conventionele medicamenteuze therapie niet doeltreffend was gebleken, onderzocht. Bij alle patiënten konden binnen een tijdsbestek van één uur zowel een conventionele röntgenfoto volgens Waters als een CT-scan van de sinus maxillaris worden vervaardigd. De verschillende opnamen werden geblinddeerd en at random aan twee onafhankelijke onderzoekers aangeboden ter beoordeling op basis van standaard radiodiagnostische criteria voor de beoordeling van zwelling van de mucosa van de sinus maxillaris. Cohen’s kappa werd berekend als maat voor inter- en intrabeoordelaar overeenstemming. De diagnostische validiteit van de projectie volgens Waters werd beoordeeld aan de hand van de sensitiviteit, de specificiteit, de positief voorspellende waarde, de aannemelijkheidsratio (‘likelihood ratio’) en de diagnostische ‘odds’ ratio. De bevindingen op de CT-scans werden daarbij beschouwd als ‘referentie standaard’.

De intra-beoordelaar overeenstemming voor Waters’ projectie en CT-scan bedroeg respectievelijk 0,96 en 0,92. De inter-beoordelaar overeenstemming bedroeg 0,76 voor Waters’ projectie en 0,92 voor CT-scan. Met de CT-scan als ‘gouden standaard’ waren de sensitiviteit en specificiteit van de Waters’ projectie om zwelling van de sinus maxillaris mucosa aan te tonen respectievelijk 83,3% en 69,2%. De positief voorspellende waarde van Waters’ projectie was 83,3%, de positieve likelihood ratio 2,7 en de diagnostische odds ratio 11,2.

Uit deze studie komt naar voren dat met behulp van conventioneel röntgenologisch onderzoek volgens Waters een zwelling van het slijmvlies van de sinus maxillaris niet betrouwbaar is te diagnosticeren. Afhankelijk van de implicaties voor de aanwezigheid van sinuspathologie lijkt aanvullend conventioneel röntgenologisch onderzoek volgens Caldwell, of het vervaardigen van CT-scans en/of het uitvoeren van neusendoscopie geïndiceerd als er enige verdenking bestaat op een preëxistente sinus pathologie.
In hoofdstuk 8 worden de verschillende bevindingen van dit onderzoek in een breder perspectief geplaatst. Bij patiënten zonder preoperatieve neusbijholte problematiek heeft de sinusbodemelatie een slechts tijdelijke effect op de fysiologie van de sinus maxillaris. De geringe ontstekingsreactie van het sinus slijmvlies dat het aangebrachte bot bedekt lijkt niet wezenlijk te verschillen van de slijmvliesreacties die kunnen worden waargenomen bij niet-geopereerde gezonde individuen. Met andere woorden: de waargenomen reacties van het sinus slijmvlies zijn mogelijker een uiting van normale fysiologische processen in de sinus maxillaris die optreden als onderdeel van het afweersysteem van de bovenste luchtwegen en moeten in dat geval niet als pathologische veranderingen worden geduid. De bij het microbiologische onderzoek waargenomen toename van het aantal positieve kweken drie maanden na de sinusbodemelatie moet vermoedelijk worden gezien als een uiting van een tijdelijk verminderde drainage van de sinus maxillaris die gewoonlijk leidt tot subklinische verschijnselen. In dit onderzoek zijn alleen patiënten onderzocht die preoperatief geen klinische en röntgenologische aanwijzingen hadden voor sinusitis. Indien preoperatief anamnestisch aanwijzingen bestaan voor een verstoorde sinus drainage, lijkt de kans op het ontwikkelen van een passagere sinusitis maxillaris na een sinusbodemelatie vergroot. Bij patiënten die in het verleden sinusitis hebben doorgemaakt, kan het uitvoeren van een elevatie van de bodem van de sinus maxillaris met autolog bot aanleiding geven tot een mogelijk recidief. Voor deze patiënten is een preoperatieve strategie beschreven, waarbij een beoordeling van de actuele conditie van de sinus maxillaris van wezenlijk belang is. Dit geldt zeker voor patiënten bij wie aanwijzingen bestaan voor een structurele verstoring van de sinus drainage. In dergelijke gevallen is een chirurgische correctie daarvan geïndiceerd voordat de sinusbodemelatie procedure wordt uitgevoerd.

Tenslotte wordt opgemerkt dat elevatie van de bodem van de sinus maxillaris een chirurgische procedure vereist waarbij hoge eisen worden gesteld aan de vaardigheden van de operateur. Perforaties van het sinus slijmvlies, onvoldoende fixatie van het aangebrachte bot, contaminatie van het operatiegebied en inadequate wondsluiting kunnen allen leiden tot slechte klinische resultaten en postoperatieve complicaties. De resultaten van deze studie laten zien dat de kans op postoperatieve sinusitis maxillaris niet is verhoogd als eventuele perforaties peroperatief worden afgedicht door hierover een corticale botplaat aan te brengen. Aan het einde van dit hoofdstuk worden richtlijnen beschreven voor het handelen bij postoperatieve transiënte en chronische sinusitis maxillaris indien dit is ontstaan ondanks grondige preoperatieve screening gericht op preventie daarvan.
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Curriculum Vitae


Vervolgens werd in 1993 met de opleiding Mondziekten en Kaakchirurgie in het Academisch Ziekenhuis Groningen aangevangen (opleiders Prof.dr. G. Boering en Prof.dr. L.G.M. de Bont), waarna in september 1997 eveneens inschrijving in het specialistenregister als kaakchirurg volgde. Sindsdien is de auteur als kaakchirurg werkzaam in het Wilhelmina Ziekenhuis te Assen en part-time als wetenschappelijk onderzoeker verbonden aan de afdeling Mondziekten Kaakchirurgie en Bijzondere Tandheelkunde van het Academisch Ziekenhuis Groningen.

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