PROPERTIES OF DENTAL IMPLANTATION IN THE POSTERIOR MAXILLA

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Summary

Objectives: The purpose of the present study was to evaluate, clinically and radiographically the properties of implantation in the edentulous posterior maxilla according to several methods. **Material and methods**: A total of 437 patients with 1184 implants in the posterior maxilla divided in 5 retrospective groups were evaluated according to different methods: the standard implantation group, which included 87 patients with 277 implants, the 1-step sinus augmentation group, which included 54 patients with 186 implants, the 2-step sinus augmentation group which included 52 patients with 164 implants, the transcrestal sinus elevation group which included 82 patients with 214 implants and the alternative group which included 162 patients with 343 implants. This group included 122 short, 28 palatal positioned, 33 pterygomaxillary, 56 tilted implants and 104 implants with cantilevered prostheses. Patients were treated consecutively between 2004-2011, and were followed up to 60 months after prostheses delivery. **Results**: A success rate of 95.3% for standard implants, 95.7% for 1-step sinus augmentation, 95.6% for 2-step sinus augmentation, 96.3% for transcrestal sinus elevation, 96.7% for short implants, 93% for palatal positioned implants, 92% for pterygomaxillary implants, 94.6% for tilted implants and 95.2% for implants with cantilevered prostheses at 5 years of follow up was obtained. The mean radiographic marginal bone loss (MBL) at 5 years of follow up was 1.8mm for standard group, 1.6mm for graft group and 1.7mm for the alternative group. No statistically significant differences were found between the groups for either of the evaluated procedures. **Conclusions**: The data from this study indicate that success rates of implants partly anchored in augmented sinuses or exclusively anchored in nonaugmented bone were similar after an observation time of 5 years. The alternative method represents an alternative therapy of others currently in use. This minimally invasive surgical procedure should be applicable in an outpatient clinic for treatment of severely resorbed posterior maxilla.

Rezumat

Particularităţile instalării implantelor dentare în sectoarele posterioare ale maxilei

La 437 pacienţi cu diverse edentaţii în sectoarele posterioare ale maxilei au fost instalate 1184 implante dentare endoosoase. În dependenţă de metodele de instalare pacienţii au fost divizaţi în 5 grupuri: 1) metoda standard – 87 pacienţi (277 implante), 2) elevaţia planşeului sinusului maxilar cu instalarea simultană a implantelor – 54 pacienţi (186 implante), 3) elevaţia planşeului sinusului maxilar cu instalarea amânată a implantelor – 52 pacienţi (164 implante), 4) elevaţia transcrestală a planşeului sinusului maxilar – 82 pacienţi (214 implante) şi grupul 5) metode alternative de instalare a implantelor – 162 pacienţi (343 implante). În ultimul grup au fost 122 implante scurte, 28 - pterigomaxilare, 28 - poziţionate palatinal, 56 - instalate angulat şi 104 implante pe care erau fixate proteze cu extenzie. Pacienţii au fost trataţi pe parcursul anilor 2004-2011. Rezultatele au fost studiate clinic şi radiografic în diapazonul 12 – 60 luni. Rata succesului a fost constatată: 95,3% în primul grup, 95,7 – în grupul doi, 95,6 – în grupul trei şi 96,3% – în grupul patru. În grupul cinci ea a fost respectiv 96,7% - la implantele scurte, 93% - la implantele poziţionate palatinal, 92% - la implantele pterygomaxillare, 94.6% - la implantele poziţionate angulat şi 95.2% la implantele cu proteze cu extenzie. Diferenţă statistică semnificativă între grupuri n-a fost observată. Studiul a demonstrat că metodele alternative de instalare a implantelor dentare în sectoarele posterioare ale maxilei sunt o opţiune viabilă de reabilitare implanto-protetică a pacienţilor.

Introduction

The rehabilitation of partially or totally edentulous maxilla with implant-supported prostheses has become common practice in the last decades with reliable long-term results [1-2]. The posterior maxilla presents its own unique set of anatomic challenges for implant placement and survival, primarily as a result of the pneumatization of the sinus and structural characteristics of the bone [3]. After tooth extraction bone loss has been shown to occur in a vertical dimension, but mostly in a horizontal dimension [4]. This occurs principally due to collapse of the buccal wall of the socket toward the lingual [5]. More recently Schropp et.al [5] have described that a reduction in residual alveolar ridge up to 50% in width may occur during the first 3 months of healing, resulting in progressive resorption of the alveolar ridge initially in bucco palatal direction because of the interruption of blood supply to the bone plate, the absence of occlusal loads [6] and pneumatization of the maxillary sinus [7]. Posterior maxillary bone is typically soft, due to its thin or absence of cortical and very medullary and spongiotic trabeculae [8]. The edentulous posterior maxilla was shown to have the least amount of residual bone height compared with other edentulous regions of the maxilla [9]. In particular, bone height significantly decreased from premolar to molar edentulous sites. The edentulous maxillary sinus expands in both inferior and lateral dimension and may even invade the canine eminence region and proceed to the lateral piriform rim of the nose. Among the factors that influence this process is heredity, the pneumatization drive of the mucous membrane of the nose, craniofacial configuration, density of the bone, growth hormons, sinus air pressure and sinus surgery [10]. Therefore bone volume classification was proposed by Lekholm and Zarb 1985, for residual jaw morphology [11]. They described five stages of jaw resorption, ranging from minimal to extreme (A, B, C, D, and E). Another bone resorption classification, which included the expansion of the maxillary sinuses, was also proposed by Cawood and Hawell in 1988 [6]. In 1985 and 1987 Misch [12] established four basic divisions of available bone for implant surgery in the edentulous jaws. Several classification systems have been proposed for assessing bone quality. In 1985, Lekholm and Zarb [11] classified bone density into four types based on the amount of cortical versus trabecular bone. In 1988, Misch proposed four bone density groups based on macro-scopic cortical and trabecular bone characteristics (D1, D2, D3 and D4) [12]. Bone density D3 is very common in the maxilla. More than half of the patients have D3 bone in the posterior maxilla, more often in the premolar region. The softest bone, D4, is most often found in the posterior maxilla (approximately 40%). A more accurate determination of bone density is made with computed tomographs before surgery or tactilely during implant site preparation. The most critical region of bone density is the crestal 7 to 10 mm of bone, as this is where most stresses are applies to an osseointegrated bone - implant contact. During the past 30 years various therapeutic strategies have been proposed to overcome these anatomic and biomechanical disadvantages with the objective of increasing the local bone volume, thus enabling the placement of implants of more than 8mm. These include underdrilling protocol [13], bicortical and tricortical anchorage, modified implant designs, the use of different bone condensers, e.g. osteotome technique [14], vertical bone augmentation, sinus floor augmentation [15]. Standard implant placement in the posterior maxilla is indicated if at least 10mm of bone is available below the sinus floor. This technique has been described by different authors [16]. According to this technique undersized or underdimensioned drilling was used [13]. In attempt to improve bone density at the implant site, the preparation of the implant bed was performed by minimal drilling and/or by condensing the bone with osteotome which has been introduced to optimize the bone density [13]. The implants could be placed monocortically, bicortically or tricortically, i.e. the apical part of the implant did or did not engage the anterior or inferior border of the maxillary sinus (bicortical), or the buccal and/or palatal cortical wall, Consequently, it seems favorable to engage as much cortical bone as possible when placing implants [17]. Bahat [16] recommended placement of a sufficient number of implants to support the occlusal load avoiding nonaxial loading. Langer et.al. [18] proposed the use of wide diameter implants. Standard implants are recommended in the posterior maxilla immediate after extraction because

residual bone usually exists around the extraction site [19].With the osteotome technique, a series of implant-shaped instruments with an increasing diameter were used to prepare the implant site by compressing bone apico-laterally, thus resulting in a local increase in bone density [14]. This approach most likely resulted in a larger portion of the implant coming into direct contact with mineralized bone, as called "press-fit" effect, which is particulary recommended for type IV bone [13]. The use of tapered implants is another option to induce a degree of compression on the cortical bone in a poor quality bone. When standard implant placement is contraindicated a variety of augmentation procedures, have been introduced to provide the osseous support necessary to permit placement of implants. In situation where the lack of bone volume is related to an enlarge maxillary sinus, elevation of the sinus floor has been advocated to permit implant placement. Introduced by Dr. Hilt Tatum in 1975 [7], the sinus lift graft organized by the Academy of osseointegration found sinus grafting should be considered a highly predictable and effective therapeutic modality [20]. Among the variety of techniques that have been described, the 3 that are the most widely used are 1. The two step lateral approach sinus elevation [21] 2. The one step lateral approach sinus elevation [22] 3. The osteotome technique (crestal approach) [23, 24]. The two step sinus elevation is the treatment of choice when the residual bone height is less than 4mm [25] and implants placement in a later stage after healing period of 6 months after sinus elevation [26]. In some cases it is possible to perform the surgery in one stage with placement of bone graft and implants simultaneously [15, 22]. However in these cases it is important to have enough crestal bone to achieve good initial stability. When the ridge residual bone height is more than 6mm, the osteotome technique can be performed. In that case implant placement is usually carried out simultaneously with sinus elevation [23]. However the sinus elevation procedure is a demanding surgical procedure and it is quite invasive. The osteotome technique has the primary advantage of being less invasive in contrast to the more invasive lateral approach. The Schneiderian membrane alone can be used as biologic autologous membrane to enable bone formation supporting by the implant only without bone graft or membrane [27]. Alternative methods in which the severely resorbed alveolar crest is used for implant placement without bone grafting have been presented in different publications [28-34] for patients who, due to general medical problems, pathologies of the maxillary sinus, advanced age or psychological reasons, cannot undergo invasive surgery such as maxillary sinus augmentation, because this procedure is more time consuming and expensive, increases morbidity, and requires a highly skilled medical-surgical team and longer treatment time. With regards to the clinical condition, there are essentially five treatments that have been proposed as alternative to sinus grafting: a) Short implants [28]. b) Tilted implants [29]. c) Pterygomaxillary implants [30]. d) Palatal positioned implants [31]. e) Prostheses with long distal cantilever [32, 33]. f) Maxillo-zygomatic implants [34]. Short implants 6 to 9mm in length are widely perceived to have a greater risk of failure compared with standard length implants [28]. A further possibility for alternative treatment is the insertion of tilted implants mesially and distally of the maxillary sinus [29]. The placement of implants in the pterygomaxillary pyramidal junction [30] can be considered as a predictable alternative to sinus augmentation and precludes the use of graft material. The placement of implants in the palatal wall of the maxilla allows maximum use of the available bone facilitating rehabilitation with implant supported fixed prostheses [31]. Zygomatic implants [34] provided the clinician with an alternative to grafting procedures. This procedure associated with some complications as the potential risk of orbital injury, the difficult surgical accessibility and visibility of this technique and patient hospitalization can be considered as a disadvantage of zygomatic implant treatment. A different treatment option to sinus elevation may be the placement of implants in the anterior maxillary sinus area with a distal extension [32, 33]. The success rates of those implants (alternative methods) are similar to or higher than those of other techniques. A careful evaluation of alternative treatments to sinus grafting is necessary to avoid more invasive surgery in many cases without reducing implant success rates. The aim of this study was to retrospectively evaluate and analyze a cohort of patients who had implants placed in the posterior maxilla with and without grafting material and

assess and identify the properties and the challenges of implant placement and survival in this unique sector.

Materials and methods

Patient selection and evaluation

The clinical material for this study has been recruited from the rehabilitation of 437 posterior edentulous patients, 221 women and 216 men (mean age 57) (Table 1) with unilateral or bilateral edentulous posterior maxillae treated with dental implants with or without bone augmentation at the private practice of the author.

Table 1 Distribution of Patients with Regard to Gender and Age

	Age						
Gender	< 20	21-30	31-40	41-50	51-60	61-70	> 71	Total
Female	16	17	19	55	54	42	18	221
Male	12	15	16	46	61	53	13	216
Total	28	32	35	101	115	95	31	437

All patients were treated between January 2004 and December 2011 with a total of 1184 consecutively placed implants(Alpha Bio, MIS, ITI, Adin, Alpha Gate) for restoration of single-tooth and partially edentulous sites of the posterior maxilla. (Table 2, 3, 4, 5).

Table 2 Enrollment Rate

Year	No. of Implants	Percentage of Total (%)
2004	85	7.2
2005	92	7.8
2006	122	10.3
2007	143	12
2008	147	12.4
2009	163	13.7
2010	196	16.6
2011	236	20
Total	1184	100%

Table 3 Distribution of the Implants (n=1184) According to Location

Posterior Maxilla	17	16	15	14	24	25	26	27
N. Placed	129	168	115	120	113	185	186	168

Table 4 Characteristics and location of the Implants Placed

Implant dimensions	No. of Implants Placed			
	1 premolar	2 premolar	1 Molar	2 Molar
Diameter				
3.3mm	84	85	64	54
3.75mm	65	69	81	75
4.2mm	85	81	97	102
5.0mm	53	54	65	70
Length				
8mm	22	28	34	38
10mm	56	69	84	76
11.5mm	68	72	78	62
13mm	62	76	89	78
16mm	42	55	48	47

The choice of treatment was based on the amount and direction of bone available for implant placement as determined by clinical and radiographic presurgical examinations. Patients were divided into 5 groups with implants placed following one of five specified surgical procedures:

a) Standard implant placement.
b) Sinus grafting procedure by lateral access with simultaneous implant placement.
c) Sinus grafting procedure by lateral access with delayed implant placement
d) Transcrestal sinus elevation combined with implants with or without graft material
e) Alternative treatment concept using preexisting bone for implant treatment.

Table 5 shows the distribution of treatment groups to patients and implants.

Table 5 Distribution of treatment groups to patients and implants

Treatment Group	No. of Patients	No. of Implants
Standard Implantation	87	277
1-Step Sinus Augmentation	54	186
2-Step Sinus Augmentation	52	164
Transcrestal Sinus Elevation	82	214
Short Implants	38	122
Palatal positioned Implants	15	28
Pterygomaxillary Implants	25	33
Tilted Implants	32	56
Implants with cantilevered prostheses	52	104
Total	437	1184

Type II bone in 45 patients, type III bone in 184 patients, type IV bone in 208 patients was present at the sites of the posterior implants .

The Standard implantation group served as a reference group: executed in situations where the vertical dimension of the residual bone was $\geq$ 10mm.Ten mm or longer implants with 3.75mm, 4.2mm and 5.0mm in diameter were placed to maintain the primary stability. 87 patients (36 males and 51 females) aged between 25 to 79 years (mean age 53 years) received a total of 277 consecutively placed standard implants (Table 6).

Table 6 Distribution of implant dimensions for standard implantation.

Length(mm)	Diameter (mm)				Total
	3.3	3.75	4.2	5.0	
10	0	12	15	8	35
11.5	0	13	34	7	54
13	14	33	46	11	104
16	23	28	33	0	84
Total	37	86	128	26	277

In this study group 45 implants in 13 patients were placed in type II bone density, 109 implants in 28 patients were placed in type III bone density and 123 implants in 46 patients were placed in type IV bone density. In type III or IV bone density, implants with greater diameter, roughened surface were preferred. Narrow implants and wide implants have been used according to standard implantation protocol. Narrow-diameter implants i.e. 3.0, 3.3mm in diameter were indicated for thin bone volume $\geq$ 4mm and were used in specific conditions such as a reduced

interradicular bone, thin alveolar crest, or replacing teeth with a small cervical diameter. Wide-diameter implants i.e. 5mm have been used to increase the ability of these implants to tolerate occlusal forces. These implants were designed to address wider sites and higher occlusal forces. The implants were placed as either monocortically, bicortically or tricortically anchored. The following basic procedural concepts were used in this study: a) Placement of sufficient No. of implants to withstand the high occlusal forces. Two standard implants for each missing molar were suggested for a single site to mimic the anatomy of the roots, if 14mm or more space between adjacent teeth was present. b) Use of wider ≥4 mm implants rather than the 3.75 mm standard design, when possible. c) Use of a threaded design implants. d) Presurgical planning of the final restoration.

The study population of 1- Step sinus augmentation group consisted of 54 patients (24 males, 30 females; average age: 53.7 years; range 37 to 70 years) (Table 7). A total of 72 sinus augmentations were performed with simultaneous implantation of 186 implants.

Table 7 Number of Patients Subjected to 1-step sinus augmentation.

Surgery Sinus Procedures	Male Patients	Female Patients	Total Lift
Bilateral Sinus Lift Procedure	10	8	36
Unilateral Sinus Lift Procedure (right side)	8	10	18
Unilateral Sinus Lift Procedure (left side)	6	12	18
Total	24	30	72

Patients with residual ridge height ≤4mm scheduled for a 2-step sinus augmentation procedure were consecutively admitted to the study. A total of 67 Sinus augmentations were performed in 52 patients (Table 8).This group comprised 23 men and 29 women with a mean age of 56.84 years (range 20-76 years). A total of 164 implants were placed 6 months after Sinus augmentation. The average remaining height of the alveolar crest below the sinus floor was 2 to 4mm. All patients showed class 4 and 5 atrophy of the posterior maxilla according to Cawood and Howell's classification [7].

Table 8: Number of patients subjected to 2-step sinus augmentation.

Surgery	Male Patients	Female Patients	Total sinus lift procedures
Bilateral sinus lift	6	9	30
Unilateral sinus lift procedure(right side)	9	11	20
Unilateral sinus lift procedure(left side)	8	9	17
Total	23	29	67

It was mandatory to thoroughly review the patients' medical history. Special attention was devoted to patient-related factors that may affect bone healing. A systematic approach includes: a) General health status b) Concomitant medication c) Allergies (Allergic sinusitis) d) Tobacco and alcohol e) Compliance was accomplished. All patients met the requirements of a strict selection protocol (Table 9).

Table 9 Criteria Used for Patient Selection
Inclusion
Presence of at least 1 mm residual bone height (RBH)
Good general health and patients with controlled medical conditions
Stable mental health condition
Ability to complete at least 24 month of clinical follow-up
Willingness to provide signed informed consent
Exclusion
Uncontrolled diabetes
Evidence of sinus pathology e.g, chronic or acute sinusitis, cysts, tumors
Presence of immunodeficiency
Use of immunosuppressive
Use of bisphosphonate
Radiation therapy in head and neck included the maxilla
Chemotherapy in the 12-month period prior to proposed therapy
Heavy smokers more than 20 cigarettes/day

Tobacco use was not considered as absolute contraindication for sinus augmentation procedure. In many situations, alternatives to implant therapy including sinus augmentation procedure were preferred.

Clinical and radiographic examination

A complete physical examination of oral hard and soft tissues was carried out for each patient, and an overall dental treatment plan was formulated. Diagnostic casts, wax-ups, and surgical guides were also used as needed. The ridge was assessed mesiodistally and buccolingually to ascertain whether it can accommodate an implant. Interarch clearance has been studied to determine space availability for the implant and crown. The prognosis and role of adjacent and opposing teeth was considered. The quantity of keratinized mucosa and the profile of the alveolar crest were evaluated: a thick mucosa and a regular alveolar crest are important prerequisites for flapless surgery and fixed prostheses. Intraoral periapical radiographs, panoramic radiographs, and computed tomographs were obtained from patients included in this study at baseline to evaluate the available bone quality and quantity, angulation of bone, selection of potential implant sites and to verify absence of pathology. Panoramic radiographs were obtained to determine the vertical bone dimension, after second stage surgery, and after prostheses placement. CT scans were obtained for patients planned for sinus augmentation to determine the osseous structure and to evaluate any pathology of the sinuses. A patient with sinusitis, sinus disease or invasive lesions was referred to ear, nose and (ENT) throat specialist for treatment before surgery procedure. The preoperative clinical and radiographic examination revealed no maxillary sinus pathology. The values obtained from the panoramic measurements were corrected for their magnification (divided by the enlargement factor 1.2) as defined by the manufacturers. CT images were in their actual size (ratio1:1). When less clinical space is available for prosthodontic reconstruction, a gingivectomy was first performed.

According to analysis of computed tomography, or panoramic imaging the prevalence, size, and location of sinus septa were addressed. Preoperative classification of bone height in the posterior maxilla according to Cawood and Hawell was done retrospectively with the help of panoramic radiographs. Bone density in the posterior maxilla was determined by the resulted tactile sense during implant site preparation following the method of Misch [12] using a physiodespenser intrasurg 300 kavo Germany. This led us to modify our surgical protocol and treatment plan according to the resulted tactile sense during implant site preparation.

The insertion torque was recorded during implant placement with the help of the torque driver (Alpha Bio Israel) or through a torque gauge incorporated within the drilling unit INTRA surg 300 (kavo) Germany. Periotest measurement was performed for all patients at implant placement, at second stage surgery, and at the start of loading (Periotest ® S device Medizintechink Gulden, Germany). Each measurement was repeated until the same value was recorded twice. Periotest value (PTV) was given in form of an implant stability degree to allow comparison between the different study groups. To determine the implant secondary stability reverse torque test (RTT) was measured at the time of second stage surgery. The RTT was evaluated for each implant separately. It was measured with a hand torque wrench (Alpha-Bio Israel) by unscrewing the implants with 20 Ncm. If interfacial failure occurred, the implant was considered as failed. In all cases peri-implant marginal bone loss (MBL) was measured on conventional periapical, digital periapical, and panromaic radiographs at the time of implant placement, loading time, after 1 year, then annually to 5 years. The measurements were carried out using the threads of the implants as the internal standard. Measurements were calculated on 2 of the panoramic imaging from each patient one taken immediately after implant placement, and one taken at the last follow-up annually to 5 years. MBL was evaluated by subtracting the bone level at the time of implant exposure from that of the most recent follow-up. The number of threads unsupported by bone at both the mesial and distal sides of each implant was counted, and the higher number was used for bone loss calculation. This result was multiplied by the implant pitches (in mm). Manufacturer provided information about the pitch of implant system used.

Surgical technique

The surgical technique for standard implantation, following the Branemark standard protocol [35] and the surgical techniques for sinus elevation and for the different alternative implantations to avoid sinus grafting have been used and have been described elsewhere. To enhance the loosely structured trabecular bone in the posterior maxilla, undersized or underdimensioned drilling was used. In attempt to improve bone density at the implant site and to enhance primary stability condensing the bone with osteotomes to locally optimize the bone density by using a final drill diameter considerably smaller compared with the implant diameter. To achieve good primary stability without creating excessive compression in the peri-implant bone, implants were inserted with a torque of at least 25-35 Ncm. Another technique used to increase primary stability involves the use of tapered implants engaging the opposing cortical bone of the sinus floor. The thin cortical bone on the crest provided improved initial stability of the implant when it was compressed against the implant neck. The use of implants with a shoulder wider than its body increased the primary stability of the implants in a way that the implant shoulder engages the cortical crestal bone. The compressed soft bone not only provided greater stability, it also initiates a good healing with a higher bone Implant Contact (BIC). A brief description of the surgical techniques applied to the different classes of atrophy is presented and described in details in each specific section of the complete thesa to avoid repetitions.

Evaluation of long-term follow-up

All patients included in this study were part of a regular recall program. The investigation, included both clinical and radiographic information obtained at base line, at the conclusion of implant placement, abutment connection, and at the time of prostheses delivery. Data were collected from the time of bone augmentation or implant placement until the last follow-up and analysed retrospectively. After prostheses delivery they were evaluated once for the first year and annually thereafter. Of 437 patients 413 presented and followed for clinical and radiographic examinations. A periapical radiograph was obtained any time the patient reported unexpected pain or discomfort or if soft tissue health worsened. The recall program included assessment of marginal bone loss, pocket depth, the plaque and gingival indices, implant mobility, and implant survival time. The initial postoperative radiograph was compared with the most recent one. Evaluated parameters were described and compared for the different surgical procedures. The images were evaluated for peri-implant conditions.

Implant success, survival and failure

Implant success was evaluated as suggested by Albrektsson et.al [1]**.** If any one of these criteria was not fulfilled, the definition of success was not met and it had to be changed to the level of survival and if the patient was dismissed, the implant was defined as not accounted for, and if the implant was mobile and was subsequently removed, it was regarded as a failure. Since failure do occur over different periods of time, early and late-failure were considered. The early failures, before loading, are regarded as due to biological reasons such as infections, surgical trauma, overheating, overload during healing. The late failures after the implants were loaded due to biomechanical factors, such as excessive load, peri-implantitis or technical problems.

Bone augmentation material

Two different grafting materials were used: anorganic bovine bone (ABB) (Bio-oss; Geistlich, Wolhusen, Switzerland) and β-Tricalcium-phosphat (β-TCP), cerasorb (Curasan, Kleinostheim, Germany), were employed as particulate grafting materials beneath resorbable collagen membrane (Bio-Gide, Geistlich) and through transcrestal sinus elevation when grafting material was used . The study population was divided into 4 groups according to the augmentation material used for sinus augmentation (Table 10).

Table10 Distribution of Patients to Grafting Groups

Group	No. of Patients	Graft
T	24	β-Tricalcium phosphate
TA	22	β-Tricalcium phosphate +50% autogenous bone
D	65	Deproteinized bovine bone
DA	52	Deproteinized bovine bone +50% autogenous bone

For the 24 patients in β-Tricalcium phosphate group (T), β-Tricalcium phosphate was used in form of cerasorb, sized, 1 to 2mm. For the 22 patients in β -Tricalcium phosphate + autogenous bone group (TA), β-Tricalcium phosphate mixed with the autogenous bone taken from the same surgical sites or from the maxillary tuberosity was used. Autogenous bone was harvested using bone scrabers, and incorporated with β-Tricalcium phosphate, which made up 50% of the mixture. In the next 65 patients, only deproteinized bovine bone was used, (Bio-oss spongiosa), with a particle size 1 to 2mm. For the 52 patients in deproteinized bovine bone and autogenous bone (DA) group, 50% of autogenous bone was added to the deproteinized bone substitute, as in group TA. During the surgical procedure, all the combinations of graft materials were mixed with patients' blood taken form the operation site.

Results

Standard implantation

Of the 277 placed and followed implants, a total of 13 implants (4.7%) failed during the follow-up period. 3 (1%) failed between placement and loading. Five more of the placed implants (1.8%) were lost between loading and the end of the first year. Additional 3 implants (1%) failed between 1 and 2 years after placement, and 2 failed (0.72%) thereafter, thus 62% of the failures occurred within a year of implant placement. The monocortical group showed 7 failures (5.1%) of the 137 placed implants. In the bicortical group, 5 failures (4.2%) of the 119 placed and followed implants. In the tricortical group one failure (4.7%) of the 21 implants placed, were found. The radiographically determined marginal bone loss, defined to mean values of 1.8 mm. The greatest change in marginal bone loss occurred between the time of implant insertion and loading. Twenty-two percent of the implants showed a bone loss exceeding 1.5mm between the time of implant insertion and loading. There were 12 minor (4.3%) complications, such as premature spontaneous implant exposures. Those requiring surgical intervention for degranulation and primary closure were considered as major complications which were seen in 6 Patients (2.2 %). In 16 implants peri-implant mucositis developed into lesions extending farther apically with associated alveolar bone loss. Angular bone defects extended around the entire

circumference of the implants and showed peri-implantitis with increasing probing depth exceeding 5 mm with occasional suppuration and radiographic loss of crestal bone, but the clinical stability was not jeopardized. In the 2 to the 5 year follow-up, 2 implants were explanted because of advanced infection to a degree where it cannot be controlled by the conventional therapeutic protocols. The survival rate was 95.3%.

1- Step sinus augmentation

A total of 54 patients (30 female and 24 male) were treated, the mean age was 56.2 years. They received 186 implants and 72 sinuses were elevated simultaneously. Thirty six unilateral (18 right and 18 left maxillary sinuses) and 18 bilateral sinus elevation procedures were performed. Normal clinical healing occurred in most patients .Any discomfort was primarily associated with tension from the swelling or hematomas. Reports of pain were negligible. Post-operative recoveries were uneventful in 52 out of 54 patients (96.3%). The healing period following sinus augmentation of 52 patients was without complications. Minor nose bleeds occurred in one case. Nine patients referred to be light smokers (<10 cig/day).Out of 186 implants placed in grafted sinuses 8 implants (4.3%) in 8 patients were removed, due to loss of integration, untreatable peri-implantitis, or chronic pain. Four implants in 4 sinuses failed to integrate prior to uncovering, and those were removed at second-stage surgery. Two of them were successfully replaced with larger diameter implants (5mm) at the time of their removal without any additional bone grafting, another 2 implants were lost between the second stage surgery and the 1 year follow up examination. Two implants were lost between 3 and 5 year follow up. All other implants resulted to be osseointegrated after 5 years of prosthetic loading (Cumulative survival rate: 95.7%).In this study, the RBH was 4mm for 23.5% of the implants placed, 5mm for 49.0% of the implants placed, and 6mm for 27.5% of the implants placed. The mean follow-up period of implants after the start of prosthetic loading was 59 months. In five sinus augmentation procedures, arterial bleeding from the bony window occurred during removing of the lateral window and was handled with pressure, cautery, and bone wax. The sinus membrane was perforated in 5 patients (6.9% of all 72 operated sinuses). A total of 16 implants were placed in the sinus perforated membrane. Of these, five perforations in five patients were associated with the failure of 6 implants. The perforation of the Schneideran membrane were repaired intraoperatively with resorbable collagen membrane (Bio-gide, Geistlich pharma Switzerland). Two implants in two cases were displaced in the maxillary sinus cavity, one of which was displaced at the time of surgery and the other which migrated several years after placement due to spontaneous implant loss. In tow procedures, graft infection occurred and the graft had to be partially or totally removed. Dehiscence of the surgical wound occurred in 2 patients treated with sinus grafting in association with horizontal guided bone regeneration (GBR). In those patients, the exposed bone graft was treated only with cautious curettage, antibiotic therapy, chlorohexidine gel, with spontaneous healing by secondary intention.

2-stage sinus augmentation

Fifty two patients, with a total of 67 sinus grafting procedures were treated. Thirty seven unilateral (20 right and 17 left maxillary sinuses) and 15 bilateral sinus elevation procedures were executed via biomaterials and autogenous bone grafting and delayed implant placement.
In all patients the grafts were placed without any major complications. Thirty patients were followed for 5 years, 18 for 4 years, and 4 for 3 years. The residual ridge height ranged between 1 and 4 mm. The mean ridge height was 2.9 mm. A total of 164 implants were placed in grafted sinuses. Of the implants placed after graft consolidation 18.0% were placed in a single stage procedure and 82% were placed in a two-stage procedure. A total of 7 implants (4.4%) failed during the observation period. Four failures (57%) occurred during the healing period, and the remaining three failures occurred within the first to 3 year of loading. Two implants placed in β-TCP were lost four weeks after insertion because of implant infection. Another two implants

were lost at second stage surgery. Three implants inserted in autogenous bone combined with either ABB or β-TCP were lost within the first year to 3 of loading. This resulted in a 5 year survival rate of 95.6%. In three sinus augmentation procedures, arterial bleeding from the bony window occurred during removing of the lateral window and was handled with pressure, cautery, and bone wax. During sinus augmentation, the sinus membrane was perforated in 5 patients (7.4% of all 67 operated sinuses). A total of 16 implants were placed in the sinus perforated membrane. Of these, four perforations in four patients were associated with the failure of 5 implants. The perforation of the Schniederan membrane were repaired intraoperatively with resorbable collagen membrane (Bio-gide,Geistlich, Switzerland). One patient (female 53 years old) developed an acute infection in the operated right maxillary sinus. After treatment of antibiotics (Augmentin 875 mg twice a day) the site had to be incised and drained under local anesthesia. Two clinical cases showed persistent signs of infection despite drainage and required an endoscopic intervention through the nasal cavity to enlarge and liberate the maxillary osteum. Four patients have developed local peri implant infection. Local irrigation of the peri-implant sulcus with chlorhexidine-diglucanate 0.2%, twice a day for two weeks was initiated in two implants. The other two implants were debrided with an open flap surgery, with these treatments, the peri-implant infection was successfully treated in all patients.

Transcrestal sinus elevation

Through crestal approach 214 implants were placed in the premolar and molar region of 82 patients. The initial residual bone height was 5.0 ± 1.5mm, and the mean length of the implants used was 9.0 ± 1.5mm, the clinically performed sinus elevation was 3.1 ± 1.6mm. Consequently, implants with 3.75mm, 4.2mm and 5mm diameter and 8mm, 10mm length were placed. In 3 patients there was a micro perforation of the schneiderian membrane, which did not effect the clinical outcome but altered bone regeneration in one patient. No other patients reported discomfort from swelling, pain, bleeding or hematomas after the operation. Eight (3.7%) of the 214 inserted implants assisted in this study group failed during the following period of 5 years. A postoperative periapical radiograph revealed a vertical height of 10mm determined by implant length. The distance between the implant apex and the initial sinus floor were 2.8 ± 1.6mm medially and 3.0 ± distally. At the apex of the implants, bone formation was less visible. Only almost 50% of the implants showed bone formation of the implant apical surface. Radiographs showed good bone consolidation around the implants. The CT scans revealed bone formation at the palatal and buccal aspects. All implants showed clinical secondary stability. A survival rate of 96.3% in this group was revealed. Follow up radiographs demonstrated radioopaque bone surrounding the implants.

Alternative group

Short implants

A total of 122 implants 8mm long were placed in 38 patients in the posterior edentulous maxilla. The patients population comprised 22 women and 16 men. All implants were functionally loaded. Four short implants 3.3% became mobile and were removed following varying years of loading. Two of them were single implants restored with single crowns, one belong to the two implant group restorted with 2 unit fixed prosthesis, the another one belong to the four implant group.One failed implant were placed in type III bone and three failed implants in type IV bone. No additional failures were observed among the 8mm implants after 3 years and thus the survival rate was unchanged by 5 years follow up, survival rate after 5 years was 96.7%.

Palatal positioned implants

Of the 28 implants placed in 15 patients into the palatal plate between the medial wall of the sinus and the hard palate, one implant was mobile at the time of abutment connection. The 1 implant was palataly tilted and placed in the molar region and was removed. Another 1 implant was lost 1 year after loading, showing early resorption around the implant. The patient reported

tension and pain in the region at the time of prostheses tightening. The mean observation period after loading was 5 years. During the 1 to 5 years follow up, neither significant radiographic changes of the bone around the implants nor discomfort of masticatory function were registered. A cumulative success rate of 93% was revealed.

Pterygomaxillary maxillary implants

A total of 33 implants were placed into the pterygomaxillary-pyramidal region in 25 patients showing partial uni-or bilateral edentulous posterior maxilla. The group comprised 14 women and 11 men aged between 35 and 79 years. Three patients have been withdrawn after the first year of loading. The remaining 22 patients were followed for five years. Of the 33 implants placed into the pterygoid plate 1was mobile at the time of abutment connection and were considered early failure. Of the remaining 32 implants one failed in the first year of loading, the second in the third year of loading. The 5 year survival rate was 92%.

Tilted implants

32 patients, with uni-or bilateral edentulous posterior maxilla (17 women and 15 men) were included in this study group. Average age was 61.3 years. A total of 56 mesially and distally tilted implants in the second premolar and second molar region were placed in 32 patients. Two tilted implants failed during the first year of loading. During the second year of loading another one implant failed too. The cumulative implant survival rate was 94.6% up to 5 years follow-up of loading.

Implants with cantilevered prosthesis

Fifty two patients, with edentulous posterior maxillae, (28 woman and 24 men) were treated with 104 implants placed in existing native bone in the second premolar region of the maxilla to support fixed prosthesis with long cantilevers. Three implants failed after one year of loading. Additional 2 implants were removed due to bone loss in the 3 to 4 years of loading. The cumulative survival rate was 95.2%

Discussion

Implant treatment of the posterior maxilla is a demanding procedure. Several recent investigations of long-term outcomes of various types of implants in the posterior maxilla have been published [1-3]. Poor bone quality is the most significant factor associated with implant failure [3]. Bone quality was related to failure in most studies [16]. More losses were found in the posterior maxilla that presented poor bone quality and severe resorption. Bucks and colleagues [36] reported 5 years succes rate of 96.6% including 416 implants placed in the posterior maxilla. Jemt and Lekholm [37] described 701 Branemark system implants placed in posterior maxillae with 5 years follow-up. They reported cumulative failure rate of 28.7% for implants placed in severely resorbed bone, versus 7.9% for those placed in better quality bone. The success rate was slightly lower in type IV bone. Lazzara and coworkers [38] who placed 529 implants in posterior maxilla, reported a success rate of 93.8%. Implant failure has been associated with several factors such poor bone quality, short length, narrow diameter, parafunction, gender, infection, implantation area and implant diameter. Bicortical fixation may improve osseointegration and reduce bone resorption [17, 39]. Minimization if site preparations may improve the potential success [13]. The placement of sufficient number of implants in the posterior maxilla is a critical aspect to support the occlusal loading. A one-to-one substitution of implants for teeth leads to overloading. The present study suggests that the placement of sufficient number of implants like the number of the teeth roots may reduce the failure rate of posterior implants, also through use of wide or double implants [18]. In a study concerning 732 implants in the maxilla Bahat [16] verified that a higher success rate depends significantly on the implant length. With short implants higher risk of loss is associated. It is generally preferable to insert longer implants if possible. With augmentation of the sinus, a more favorable initial

situation was created which made the insertion of longer implants possible. The augmentation group in this study which included 350 implants in 139 augmented sinuses via one and two stage surgery was evaluated. No clinically significant differences were found between implants placed in the one or two stage surgery. However, whether sinus floor augmentation is preferable to implantation in the unaugmented posterior maxilla has not yet been completely determined. Implant survival in grafted posterior maxilla has undergone steady improvement over the past 25 years. Lekholm et al [40] reported a 77% overall 3 years survival rates for implants placed in augmented sinuses. In 2005 Wiltfang et al [26] showed an overall 5 year success rate of 93.1% for implants placed in augmented sinuses. The current findings of overall 99.3% of 3-years post loading survival rate of implants placed in augmented sinuses is a evidence of the trend of improvement. The high level of knowledge of dental implants and a deeper understanding of implant surface bone interaction have contributed to the improved survival rates. Numerous studies indicate that modifications to the implant placement, surgical technique, the implant surface and the implant macro design are particularly important to the survival of implants. Some authors postulate that a minimum of 10mm remaining bone is required for successful implantation without augmentation procedures in the maxilla. Neukam et al [41] defines the limit between 8 and 10mm. The placement of short implants with a modified technique, successful use of pterygomaxillary, tilted, palatal positioned and zygomatic implants has recently been reported, and it has been suggested that such modified implant placement may resolve most cases without grafts, or at any rate involve a smaller grafting procedure [42]. Meraw et al [43] concluded after a retrospective review of 542 patients that grafting procedures were required relatively infrequently (4%) in the general population. Bruschi et al [44] describe first the method of localized management of the sinus floor without bone grafts or membranes. This method used bioabsorbable collagen as a plunger. The authors reported on 499 implants in 303 patients with a success rate of 97.5% for 2 and 5 years of loading by residual bone height at least 5 to 7mm. The sinus was raised by an average of 9.12mm using collagen. It is controversial whether or not the collagen can be considered as graft material. This material may be used as space maker for bone formation and a shock-absorbing material. Other studies using the osteotome technique showed an average gain in bone height of 3 to 3.5mm. Leblebicioglu et al [45] recently evaluated implants placed in 40 sinuses using osteotome technique without graft material, membrane or collagen. They reported on success rate of 97.3% and reported of mean value of gained bone height of 3.9$\pm$1.9mm. Topalo et al [27] evaluated recently the survival rate of implants placed through transcrestal approach without any grafting material. Transcrestal approach without any graft material certainly avoids the risk of graft material migration into the sinus, may causing to transient or chronic sinusitis in 10% to 20% of sinus elevation cases. Toffler [46] suggested that a minimal implant length of 8.5mm or more was adequate. In the present study bone gain was visible in all cases and was between 3.0 mesially and 3.2 mm distally less than the initial projection of the implants in the sinus because of bone remodeling. A number of investigators have specifically studied the predictability of short implant [47]. In a multicenter study with a 1-to7 years follow-up, Bruggenkate and coworkers [48] reported an absolute survival rate of 97% for 253 short (8mm) implants. The reliability of short implants according to the literature is controversial with a number of studies concluding that shorter implants showed more failure. Tawil [47] however found no significant difference between survival rates of short (6 to 8.5mm long) versus 10mm long Branemark system implants. Results from Straumann implants showed that length is not a determining factor in implant loss. A further factor that could potentially affect the survival of short implants is the use of splinting. In this study all implants placed in adjacent sites were splinted, irrespective of implant length. In the present study, the success rates calculated for implants are favorable as those reported by a numerous of other investigators. The decision to use short implants or to perform a sinus augmentation with longer implants was made after consultation with the patient considering age, gender, general health condition, medical records and others. The combination of poor bone quality and short implants would result in less mechanical stability. Bahat [16] did not find a significantly different success rates between type

IV bone and bone of type II and III. Controversially Goodacre and coworkers [49] found that 4% of the implants placed in bone of type I, II and III were lost, while 16% of those placed in type VI bone failed. Since maxillary bone is usually poor in quality, it may have contributed to the increased failure rates in some studies. The trend should be given to the possibilities of implant placement using the anatomic features of the arches, without the use of bone grafting procedures, which may be associated with serious complications. The tilted implant approach solved a number of problems in those patients [50]. It was shown that tilted implants offered excellent support for prostheses and thus enhanced the possibility for simpler rehabilitation of patients with severely resorbed arches, without a higher incidence of biomechanic complications [51]. Rangert [52] described tilting of implants in the premolar and molar regions improving load distribution on the implants. Ivanoff [17] recently showed that the stability of bicortically anchored implants much better than those implants supported by only one cortex. Optimal stability would be achieved by placing the implant along any cortical plate. Mesially, distally or palatally tilted implants that are placed close to the anterior and posterior sinus walls, tangential to the palatal concavity in the maxilla can be expected to provide acceptable support for fixed prostheses in areas of maximal occlusal loading. Additional tilting of these anterior implants in the palatal direction is recommended by remaining adjacent natural tooth to avoid collision of the implant with roots of the adjacent teeth, since their roots are situated closer to the buccal surface. Titled implants may achieve the same outcome as implants placed in an upright position. Placement of the 2 posterior implants in strategic positions together with the anterior implants can provide a predictable implant supported prostheses [52]. The head of the implant may be placed in a more favorable posterior position with a respect to load distribution, anchoring the implants in a denser bone and allowing the use of longer implants. It is recommended that this technique be adopted only by expert clinicians with surgical skills. In this study tilting of the implants did not affect the marginal bone resorption pattern. This corresponds with data obtained by other authors [51]. Placement of implants in the pterygomaxillary region [53] is a predictable alternative treatment to avoid sinus augmentation in the rehabilitation of patients with edentulous posterior maxilla. The placement of implants in pterygomaxillary-pyramidal junction provides the use of preexisting bone. Thus numerous reports attribute to these implants success rates that are correspond to other techniques [54]. The present study demonstrate 33 implants inserted in the pterygomaxillary region with the survival rate of 92% similar to the overall survival rate reported in other studies in grafted maxillae. Implants with cantilevered prostheses represent a valid treatment modality without a high risk of complications. No detrimental effects can be expected on bone levels due to the presence of a cantilever extension [32, 33]. The methods described for the treatment of edentulous posterior maxilla represents an alternative therapy to several others currently in use.

Conclusion

The posterior maxilla represents its own unique set of anatomic and surgical challenges, due to structural characteristics of the bone and the sinus pneumatization. A success rate of 95.3% for standard implants, 95.7% for 1-step sinus augmentation, 95.6% for 2-step sinus augmentation, 96.3% for transcrestal sinus elevation, 96.7% for short implants, 93% for palatal positioned implants, 92% for pterygomaxillary implants, 94.6% for tilted implants and 95.2% for implants with cantilevered prostheses at 5 years follow up obtained in this study is a reasonable expectation for implants placed in the posterior maxilla. Since the posterior maxilla has the greatest occlusal need as well as the greatest surgical demand, precise treatment planning is crucial to success. Implants placed in areas with inadequate residual crestal bone were statistically associated with implant failure. It appears that there are risk factors associated with maxillary posterior implant failure. The data from this study indicate that success rates of implants partly anchored in augmented sinuses or exclusively anchored in nonaugmented bone were similar after an observation time of 5 years. Hence the implant anchorage provided by the bone was capable of standing with prosthetic loading, regardless of the clinical procedure chosen

for augmentation and regardless of where it was derived, from nonaugmented, or partly augmented bone. Within the limitations of this study, encouraging results in favor of the use of preexisting bone for implant placement in the atrophic posterior maxilla were obtained. The surgical methods reduce the duration of surgery and treatment time, thus reducing the costs, patients discomfort and risks of morbidity. It should also increase patient acceptance avoiding a second surgical area. More studies are required to determine whether the success rate can be improved.

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