Maxillary Overdentures Supported by Anteriorly or Posteriorly Placed Implants Opposed by a Natural Dentition in the Mandible: A 1-Year Prospective Case Series Study

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ABSTRACT

Background: For maxillary overdenture therapy, treatment guidelines are missing. There is a need for longitudinal studies.

Purpose: The purpose of this 1-year prospective case series study was to assess the treatment outcome of maxillary overdentures supported by six dental implants opposed by natural antagonistic teeth in the mandible.

Materials and Methods: Fifty patients were treated with a maxillary overdenture supported by six dental implants, either placed in the anterior region ($n = 25$ patients) or in the posterior region ($n = 25$ patients). Items of evaluation were the following: survival of implants, condition of hard and soft peri-implant tissues, and patients' satisfaction.

Results: One-year implant survival rate was 98% in the anterior group and 99.3% in the posterior group. Mean radiographic bone loss in the anterior and posterior groups after 1 year of loading was 0.22 and 0.50 mm, respectively. Mean scores for plaque, calculus, gingiva, bleeding, and pocket probing depth were low, and patients' satisfaction was high, with no differences between the groups.

Conclusion: Six dental implants placed in either the anterior region or the posterior region of the edentulous maxilla, connected with a bar, and opposed by antagonistic teeth in the mandible supply a proper base for the support of an overdenture.

KEY WORDS: case series, dental implants, edentulous maxilla, healthy ageing, overdenture, prospective

INTRODUCTION

Edentulous patients often experience problems with their complete dentures. Lack of stability and retention of their denture, together with a decreased chewing ability, are the main complaints of these patients.[1] Implant-supported overdentures are a successful therapy. Currently, there are evidence-based treatment guidelines for the edentulous mandible involving stage of resorption and number of implants,[2,3] as well as that long-term results are available of mandibular overdenture therapy.[4,5] For maxillary overdenture therapy, however, treatment guidelines are missing and there is still a need for longitudinal studies with clear and

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standardized evaluation criteria to establish evidence-based treatment planning principles.[6–8]

Quality and volume of remaining bone, and number and position of implants are factors that influence success of implants and prosthesis in the upper jaw.[9] In a systematic review with meta-analysis on maxillary overdentures,[7] the authors stated a survival rate of 98.2% per year in case of six implants and a bar anchorage, a survival rate of 96.3% in case of four implants and a bar anchorage, and a survival rate of 95.2% in case of four implants and a ball anchorage. However, no distinction was made between positions of implants in the various studies reviewed in that systematic review. A retrospective study by Krennmair and colleagues,[10] that compared anterior with posterior implants in the edentulous maxilla did not find differences in implant outcome. Sanna and colleagues[11] performed a retrospective evaluation of implant-supported overdentures in the maxilla. A number of these patients had a full or partial dentition in the mandible. The cumulative survival rate after 10 years of function was 99.3% if four to six interconnected implants supported the overdenture.

Antagonistic natural teeth might be a risk factor for maxillary overdentures but are not a contraindication. A limited number of studies stated a relationship between antagonistic natural teeth and a maxillary overdenture but could not find a significant difference.[12] The reason for being a risk factor might be a greater mastication force and harmful lateral forces to implants due to an altered occlusion concept.[13–15] A bilateral balanced occlusion concept of conventional removable dentures is often used in overdenture therapy.[16] In case of natural teeth in the antagonistic jaw, this is however often not possible because the occlusion is dictated by the anatomic form and (compromised) position of the natural teeth. It is advocated to apply an occlusal situation that is comfortable to the patient, stable, and without interferences in that case, rather than any preconceived philosophy of occlusion.[17]

The purpose of this 1-year prospective case series study was to assess the treatment outcome (survival of implants, condition of hard and soft peri-implant tissues, and patients' satisfaction) of maxillary overdentures supported by six anteriorly or six posteriorly placed implants opposed by natural antagonistic teeth in the mandible.

MATERIALS AND METHODS

Patient Selection

Between January 2006 and December 2009, consecutive patients were selected with an edentulous maxilla and with natural antagonistic teeth in the mandible (minimum of six teeth present from left lower cuspid to right lower cuspid) from the Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, Groningen, the Netherlands. The patients had been referred by their general dental practitioner because of a reduced stability and insufficient retention of their maxillary conventional denture. Inclusion criteria for the study were an edentulous period in the upper jaw of at least 1 year, the presence of healthy mandibular teeth, and a healthy periodontium. Excluded were patients with American Society of Anesthesiologists score ≥ III,[18] who were smoking, with a history of radiotherapy in the head and neck region, with a history of preprosthetic surgery, or with previous implant placement. The patients were informed about the treatment option of overdenture treatment with placing six implants in the maxilla and about the extra efforts associated with the study (questionnaires and evaluation visits) before they gave their written consent to participate. The study was approved by the Medical Ethical Committee of the University Medical Center Groningen.

Allocation to Study Groups

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 anteroposterior relationship of the maxilla to the mandible. The radiographs were also screened for sinus pathology. In all cases, a diagnostic setup of the planned overdenture was made to get more insight in the available dimensions for the bar-supported attachment system and overdenture. If there was an adequate bone volume in the region between the first premolars in the anterior area of the maxilla (height at least 12 mm, measured on a radiograph; width at least 3 mm, estimated by manual palpation) to place the implants and a sufficient intermaxillary space for a bar-supported attachment system in this region, patients were assigned to the so-called "anterior group." If there was not an adequate bone volume in the anterior area of the maxilla or not a sufficient intermaxillary space for a bar-retained attachment system in this

region, patients were assigned to the so-called "posterior group."

Treatment Procedures

All surgical procedures were performed by one experienced oral and maxillofacial surgeon. The prosthetic procedure was accomplished by three experienced prosthodontists and manufacturing of the superstructure was done by a single experienced dental laboratory.

Surgical Procedure in the Anterior Group. Six dental implants with a length of at least 11 mm and a diameter of 4 mm were inserted in the anterior region of the maxilla in a two-stage procedure (OsseoSpeed™ 4.0 S dental implants, Astra Tech AB, Mölndal, Sweden). The implants were placed in predefined positions with a surgical template in a two-stage procedure. Small dehiscences were covered with bone harvested from the mandibular retromolar area and anorganic bovine bone (Geistlich Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland) and subsequently with a resorbable membrane (Geistlich Bio-Gide®, Geistlich Pharma AG). If the most distally implants had to be placed in an anterior extension of the maxillary sinus, local sinus floor elevation surgery was performed in that region with bone harvested from the mandibular retromolar area. Two weeks after implant placement, the patient was allowed to wear the dentures again after adjustment of the prostheses in the area of the implants and relining with a resilient lining material (Soft Liner; GC Corporation, Tokyo, Japan). After a 3-month osseointegration period, second-stage surgery was performed and healing abutments (Uni Healing Abutments, Astra Tech AB) were placed. The denture was adjusted again in the area of the healing abutments and relined with a resilient lining material. The patient was given oral hygiene instructions.

Surgical Procedure in the Posterior Group. An augmentation procedure was performed under general anesthesia, and a bone graft was harvested from the anterior iliac crest.[19,20] For 2 weeks, the patient was not allowed to wear the denture. Then, acrylic resin was removed from the denture in those areas that could contact the grafted sites. Furthermore, the denture was relined with a resilient liner (Soft Liner; GC Corporation). After a 3-month healing period, six dental implants were inserted in the maxilla in a one-stage procedure (Straumann Standard SLA® implants; Ø 4.1 mm, length 12 mm, RN, Institut Straumann AG, Basel, Switzerland). The implants were placed into the grafted sites in the posterior area with a surgical template in a one-stage procedure. Two weeks after implant placement, the patient was allowed to wear the dentures again after adjustment of the denture in the area of the implants and relining with a resilient lining material. The patient was given oral hygiene instructions.

In the anterior region, bone-level implants were used. The reason for this is because small dehiscences could occur. These had to be covered with bone harvested from the mandibular retromolar area and anorganic bovine bone and subsequently with a resorbable membrane. In the posterior region, soft tissue-level implants were used. Because of the already performed augmentation procedure with a bone graft harvested from the anterior iliac crest, the assumption was made that there would be enough bone at implant placement.

Prosthetic Procedure. In both groups, after a 3-month osseointegration period of the implants, the prosthesis fabrication procedures were initiated. Custom acrylic resin impression trays (lightplast base plates; Dreve Dentamid GmbH, Unna, Germany) were fabricated with openings for screw-retained impression copings. In the anterior group, the healing abutments were replaced by 20° Uni Abutments (Astra Tech AB). Impression copings were attached to the abutments (anterior group) or directly to the implants (posterior group) with the integral positioning screw. The final complete arch impression was made with polyether material (Impregum F; 3 M ESPE, Minneapolis, MN, USA). A composite resin record base (lightplast base plates; Dreve Dentamid GmbH) with a wax occlusion rim was used to determine the occlusal vertical dimension and to record the maxillomandibular relationship. Acrylic resin artificial teeth (Ivoclar SR Orthotyp DCL and Ivoclar Vivodent PE, Ivoclar Vivadent AG, Schaan, Liechtenstein) were selected and arranged on the record base for a trial arrangement. A predefined occlusion concept was not followed; the artificial teeth were occluding the antagonistic posterior natural teeth without disturbing interferences with lateral of protrusive excursions. The final superstructure consisted of a milled titanium bar, screw retained to abutments or implants, and an overdenture with built-in cobalt chromium reinforcement

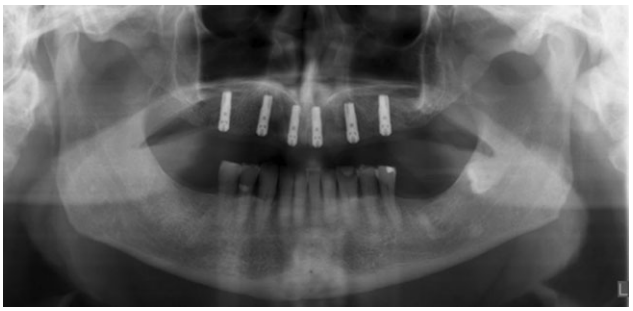

Figure 1 Panoramic radiograph of a patient with six dental implants in the anterior region of the maxilla.

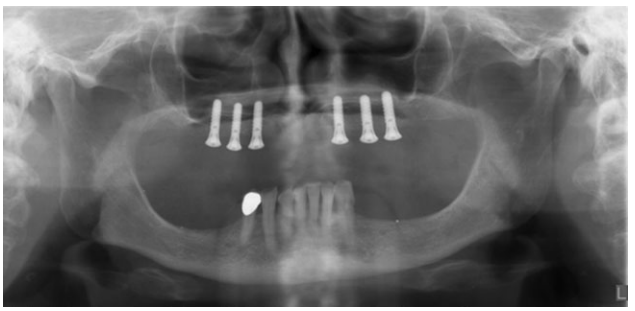

Figure 3 Panoramic radiograph of a patient with six dental implants in the posterior region of the maxilla.

structure and gold retentive clips attached to it.[21] A partial mandibular denture was made simultaneously with the maxillary overdenture in case of a shortened dental arch and when desired by the patient. The patient was instructed in hygiene procedures associated with the dentures and the bars and scheduled for routine maintenance recalls (Figures 1–4).

Analysis

Outcome measures were implant survival and the change of peri-implant bone level from loading of the implants by the overdenture to 12-month follow-up. Next to this, soft tissue conditions (plaque index, presence of calculus, gingival index, sulcus bleeding index, and pocket probing depth) were scored after placement of the overdenture and 12 months thereafter. Differences in patients' satisfaction before treatment and 12 months after placement of the overdenture were scored. Occlusal parameters were scored at the 12-month evaluation period.

Implant Survival. Loose and lost implants were scored any time after placement. Mobility of implants was checked at each evaluation period after removing of the bar.

Change of Peri-Implant Bone Level. Standardized intraoral radiographs were taken after placement of the overdenture and 12 months thereafter. The radiographs were taken according to a long-cone paralleling technique with a custom-made standardized x-ray device.[22] This device could be attached on the bar to secure standardized depiction of the peri-implant marginal bone level. The digital images were analyzed using computer software to perform linear measurements on digital radiographs. The known implant dimension was used as a reference to transform the linear measurements into millimeter. Mesial and distal bone changes in this region were considered as peri-implant bone changes and were defined as the difference in bone height between the radiograph taken immediate after loading of the implants with the overdenture and the radiograph 12 months later.

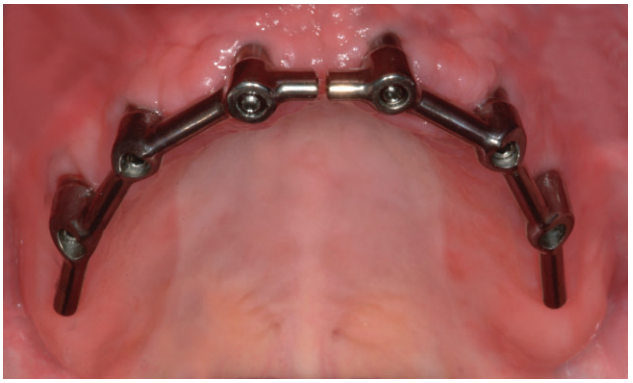

Figure 2 Intraoral view of a bar superstructure on six dental implants in the anterior region of the same patient as in Figure 1.

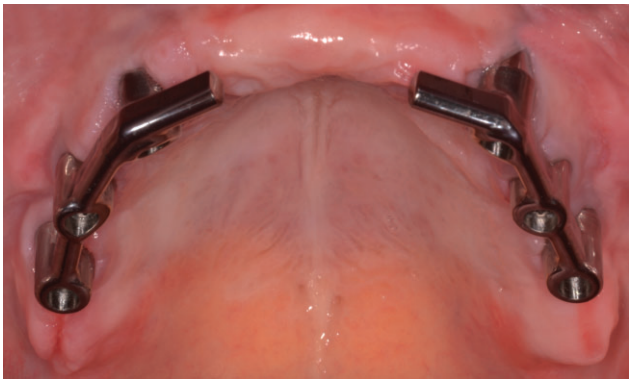

Figure 4 Intraoral view of a bar superstructure on six dental implants in the posterior region of the same patient as in Figure 3.

Clinical Parameters. For the presence of plaque, the index according to Mombelli and colleagues[23] was used (score 0: no detection of plaque, score 1: plaque can be detected by running a probe across the smooth marginal surface of the abutment and implant, score 2: plaque can be seen by the naked eye, and score 3: abundance amount of plaque). The presence of calculus (score 1) or the absence of calculus (score 0) was scored. To qualify the degree of peri-implant inflammation, the modified Löe and Silness index[24] was used (score 0: normal peri-implant mucosa, score 1: mild inflammation; slight change in color and slight edema, score 2: moderate inflammation; redness, edema, and glazing, and score 3: severe inflammation; marked redness and edema, ulceration). For bleeding, the bleeding index according to Mombelli and colleagues[23] was used (score 0: no bleeding when using a periodontal probe, score 1: isolated bleeding spots visible, score 2: a confluent red line of blood along the mucosa margin, and score 3: heavy or profuse bleeding). Probing depth was measured at four sites of each implant (mesially, labially, distally, and lingually) by using a periodontal probe (Merit B, Hu Friedy, Chicago, IL, USA) after removal of the bar; the distance between the marginal border of the mucosa and the tip of the periodontal probe was scored as the probing depth.

Patients' Satisfaction. Patients' satisfaction with their overdenture was assessed using a validated questionnaire.[25] This questionnaire focused on complaints and consisted of 54 items. It was originally divided into six scales:

A. nine items concerning functional problems of the lower denture;
B. nine items concerning functional problems of the upper denture;
C. eighteen items concerning functional problem complaints in general;
D. three items concerning facial aesthetics;
E. three items concerning accidental lip, cheek, and tongue biting ("neutral space");
F. twelve items concerning aesthetics of the denture.

The extent of each specific complaint could be expressed on a four-point rating scale (0 = no complaints, 1 = little, 2 = moderate, and 3 = severe complaints). Because there was no lower denture present, scale A was left out of the questionnaire.

All patients were requested to fill out a "Chewing ability" questionnaire.[26] In this questionnaire, patients gave their opinion about the ability to chew nine different kinds of food on a three-point rating scale (0 = good, 1 = moderate, and 2 = bad). The items were grouped into three scales, being soft food, tough food, and hard food. Next to these questionnaires, the patient's overall denture satisfaction was expressed on a 10-point rating scale (1 = very bad to 10 = excellent).

Patients' satisfaction was scored before the start of the treatment and 12 months after placement of the overdenture.

Occlusal Parameters. Occlusion of each patient was scored at the 12-month evaluation period. The following subdivisions were made:

- presence or absence of a complete natural dentition in the mandible (a complete natural dentition was defined as the presence of at least a mandibular arch of first left mandibular molar to first right mandibular molar);
- presence or absence of at least three occluding pairs on each side;
- presence or absence of a bilaterally balanced occlusion.

Data Collection and Statistical Analysis

Data collection and analysis of the radiographs were done by the same observer. The worst score per implant of the clinical and radiographic parameters was used in the data analysis. Survival was presented at implant level. Differences between evaluation periods were tested with a paired Student's *t*-test. Differences between study groups were tested with an independent Student's *t*-test. Analysis was done with PASW Statistics 18.0 (SPSS Inc.: An IBM Company, IBM Corporation, Chicago, IL, USA). In all tests, a significance level of 0.05 was chosen.

RESULTS

Fifty patients were included in the study during the selection period, of which 25 in the anterior group and 25 in the posterior group. All patients originally included in the anterior group could be treated in the anterior region; this means that there appeared to be enough bone after reflection of the soft tissues for initial stability of the implants. Baseline characteristics of the study groups are depicted in Table 1. All these patients

TABLE 1 Baseline Characteristics of the Study Group with Anterior Implants (Anterior Group) and the Study Group with Posterior Implants (Posterior Group)

Group	Anterior Group ($n = 25$)	Posterior Group ($n = 25$)
Mean age in years (SD, range)	58.4 (8.3, 42–73)	59.1 (9.7, 42–74)
Gender (number of male/ female)	14/11	10/15
Mean edentulous period upper jaw in years (SD, range)	11.1 (11.7, 1–40)	20.6 (12.3, 2–40)
Number of maxillary dentures (SD, range)	2.4 (2.0, 1–10)	3.3 (1.7, 1–8)
Age present maxillary denture (SD, range)	3.3 (2.9, 1–12)	4.1 (5.0, 1–25)
State of natural dentition lower jaw (in number of patients)		
Presence of complete natural dentition: yes/no	9/16	7/18
Presence of at least three occluding pairs on each side: yes/no	14/11	13/12
Presence of bilaterally balanced occlusion: yes/no	3/22	2/23

completed the 1-year evaluation period. Postsurgery, no complications were reported related to insertion of the implants or to the donor site of bone. Three implants were lost in two patients of the anterior group, both during the osseointegration period. Because a bar superstructure could still be made, it was decided not to replace the implants. One implant was lost during the osseointegration period in the posterior group. Also in this case, the lost implant was not replaced. One-year postloading survival rate of implants was 98% in the anterior group and 99.3% in the posterior group. Survival rate of overdentures was 100% in both groups. The mean loss of marginal bone between baseline (loading of the implants) and the 1-year evaluation was 0.22 mm (SD 0.29) in the anterior group and 0.50 mm (SD 0.68) in the posterior group (Table 2). The mean scores of the indices for plaque, calculus, gingiva, and bleeding were very low (Table 3). The mean probing depth (see Table 3) was 4.3 mm at the 1-year evaluation period in both groups. Mean scores of the questionnaires focusing on the complaints of the patients and chewing different kinds of foods, together with the overall satisfaction score, are listed in Table 4. All scores improved significantly between pretreatment and posttreatment assessment, except for "aesthetics" in the anterior group and "neutral space" in the posterior group. Differences in patients' satisfaction between the study groups at the pretreatment and the posttreatment evaluation period are listed in Table 5. After 1 year, there were no significant differences between the groups. Mean score of functional complaints about upper denture, mean scores of chewing ability of soft, tough, and hard food, and the overall satisfaction score, 1 year after loading of the implants, of the different subdivisions of occlusal state of the combined study groups are listed in Table 6. There were no significant differences in patients' satisfaction in any of the subdivisions.

DISCUSSION

This study demonstrated that six dental implants placed in either the anterior region or posterior region of the edentulous maxilla, connected with a bar, and opposed

TABLE 2 Mean Values (SD) of Bone Loss in Millimeter with Frequency Distribution 1 Year after Loading of the Implants of the Study Group with Anterior Implants (Anterior Group) and the Study Group with Posterior Implants (Posterior Group)

	Anterior Group ($n = 147$ implants)	Posterior Group ($n = 149$ implants)
Mean (SD)	0.22 mm (0.29)	0.50 (0.68)
0–0.5 mm	90%	70%
>0.5–1.0 mm	7%	17%
>1.0–1.5 mm	2%	7%
>1.5–2.0 mm	0%	2%
>2.0 mm	1%	4%

TABLE 3 Mean Values and Standard Deviations of Plaque Index (Possible Score 0–3), Calculus Index (Possible Score 0–1), Gingival Index (Possible Score 0–3), Bleeding Index (Possible Score 0–3), and Probing Depth in Millimeter after Placement of the Overdenture (T_0) and 1 Year after Placement of the Overdenture (T_{12}), and Possible Significant Differences between the Time Periods of the Study Group with Anterior Implants (Anterior Group) and the Study Group with Posterior Implants (Posterior Group)

	Anterior Group			Posterior Group		
	T_0 ($n = 25$)	T_{12} ($n = 25$)	Significance	T_0 ($n = 25$)	T_{12} ($n = 25$)	Significance
Plaque index (SD)	0.2 (0.5)	0.2 (0.4)	ns	0.1 (0.3)	0.2 (0.4)	ns
Calculus index (SD)	0.0 (0.0)	0.0 (0.0)	ns	0.0 (0.0)	0.0 (0.0)	ns
Gingival index (SD)	0.1 (0.2)	0.2 (0.4)	ns	0.1 (0.3)	0.1 (0.3)	ns
Bleeding index (SD)	0.4 (0.6)	0.3 (0.5)	ns	0.7 (0.6)	0.6 (0.6)	ns
Probing depth in millimeter (SD)	4.2 (1.0)	4.3 (1.0)	ns	4.2 (0.9)	4.3 (1.0)	ns

ns = not significant.

to antagonistic natural teeth in the mandible supply a proper base for the support of a maxillary implant-supported overdenture. The 1-year implant survival rate was high in both regions, peri-implant health was high, peri-implant bone loss was low, and patients were very satisfied.

The systematic review with meta-analysis of Slot and colleagues[7] stated that there are no studies specifically addressing survival rate of implants in the edentulous maxilla opposed by natural antagonistic teeth in the mandible as most studies do not reveal the state of opposing dentition or it is just mentioned that all kinds of opposing dentition are present. The same systematic review reported a 1-year implant survival rate of 98.2% for six implants with a bar-supported overdenture with all kinds of opposing dentitions. The 1-year implant survival rates of the present study are comparable. Sanna and colleagues[11] reported a cumulative survival rate of 99.3% after 10 years of function. This survival rate is comparable with the 1-year results of the present study. Krennmair and colleagues[10] compared survival rates of implants placed in anterior regions (four implants) and

TABLE 4 Mean Score of Five Scales Concerning the Denture Complaints (Possible Range 0–3), Mean Scores of Chewing Ability of Soft, Tough, and Hard Food (Possible Range 0–2), Overall Satisfaction Score (Possible Range 1–10) before and 1 Year after Treatment, and Possible Significant Differences between the Time Periods of the Study Group with Anterior Implants (Anterior Group) and the Study Group with Posterior Implants (Posterior Group)

	Anterior Group			Posterior Group		
	Pretreatment ($n = 25$)	1 Year ($n = 25$)	Significance	Pretreatment ($n = 25$)	1 Year ($n = 25$)	Significance
Functional complaints about upper denture (SD)	1.2 (0.5)	0.1 (0.1)	$p < .001$	1.6 (0.4)	0.2 (0.2)	$p < .001$
Functional complaints in general (SD)	0.9 (0.5)	0.1 (0.1)	$p < .001$	1.1 (0.6)	0.1 (0.1)	$p < .001$
Facial aesthetics (SD)	0.7 (0.8)	0.1 (0.2)	$p < .001$	1.2 (1.0)	02 (0.5)	$p < .001$
"Neutral space" (SD)	0.7 (0.6)	0.2 (0.3)	$p = .001$	0.5 (0.9)	0.4 (0.5)	ns
Aesthetics (SD)	0.2 (0.3)	0.1 (0.3)	ns	0.4 (0.4)	0.1 (0.2)	$p = .001$
Soft food (SD)	0.2 (0.3)	0.0 (0.0)	$p = .003$	0.5 (0.5)	0.0 (0.0)	$p < .001$
Tough food (SD)	1.1 (0.6)	0.1 (0.3)	$p < .001$	1.1 (0.6)	0.1 (0.2)	$p < .001$
Hard food (SD)	1.8 (0.4)	0.2 (0.5)	$p < .001$	1.7 (0.4)	0.3 (0.4)	$p < .001$
Overall satisfaction score (SD)	4.3 (1.4)	8.8 (0.9)	$p < .001$	3.6 (1.6)	8.6 (0.9)	$p < .001$

ns = not significant.

TABLE 5 Mean Score of Five Scales Concerning the Denture Complaints (Possible Range 0–3), Mean Scores of Chewing Ability of Soft, Tough, and Hard Food (Possible Range 0–2), Overall Satisfaction Score (Possible Range 1–10) before and 1 Year after Treatment, and Possible Significant Differences between the Study Group with Anterior Implants (Anterior Group) and the Study Group with Posterior Implants (Posterior Group) before Treatment and at 1 Year

	Pretreatment			One Year		
	Anterior Group ($n = 25$)	Posterior Group ($n = 25$)	Significance	Anterior Group ($n = 25$)	Posterior Group ($n = 25$)	Significance
Functional complaints about upper denture (SD)	1.2 (0.5)	1.6 (0.4)	$p = .012$	0.1 (0.1)	0.2 (0.2)	ns
Functional complaints in general (SD)	0.9 (0.5)	1.1 (0.6)	ns	0.1 (0.1)	0.1 (0.1)	ns
Facial aesthetics (SD)	0.7 (0.8)	1.2 (1.0)	ns	0.1 (0.2)	02 (0.5)	ns
"Neutral Space" (SD)	0.7 (0.6)	0.5 (0.9)	ns	0.2 (0.3)	0.4 (0.5)	ns
Aesthetics (SD)	0.2 (0.3)	0.4 (0.4)	$p = .036$	0.1 (0.3)	0.1 (0.2)	ns
Soft food (SD)	0.2 (0.3)	0.5 (0.5)	$p = .023$	0.0 (0.0)	0.0 (0.0)	ns
Tough food (SD)	1.1 (0.6)	1.1 (0.6)	ns	0.1 (0.3)	0.1 (0.2)	ns
Hard food (SD)	1.8 (0.4)	1.7 (0.4)	ns	0.2 (0.5)	0.3 (0.4)	ns
Overall satisfaction score (SD)	4.3 (1.4)	3.6 (1.6)	ns	8.8 (0.9)	8.6 (0.9)	ns

ns = not significant.

implants placed in posterior regions (six to eight implants) in a retrospective study. One-year survival rates were 98.4% for the anterior region and 97.4% for the posterior region. Again, these numbers are comparable to the results of the present study. This outcome suggests that the type of antagonistic dentition does not have influence on the outcome of implants in the maxilla.

Due to the different positions of the implants in the study groups and the different implant systems used, it was decided not to compare survival rates and clinical and radiographic scores of the different groups with each other. Comparison of patients' satisfaction, on the other hand, seems justified because overdenture therapy as such is evaluated.

The mean loss of marginal bone between baseline (loading of the implants) and the 1-year evaluation was 0.22 mm (SD 0.29) in the anterior group and 0.50 mm (SD 0.68) in the posterior group. This is well within the limits as formulated by Albrektsson and colleagues[27] being 1-mm bone loss during the first year and subsequent annually 0.1 mm. This phenomenon of up to 1-mm bone loss has been described by Adell and colleagues[28] and is thought to be related to maturation of bone after implant placement and adaptation of bone to withstand functional forces. In the present study, bone loss during the first year was very small which could be due to the neck design of the implants used.[29–31] OsseoSpeed 4.0 S dental implants have a platform switch and surface roughness up to the neck of the implant and Straumann Standard SLA implants have no implant-abutment connection, thus avoiding a possible micro-gap at the bone level.

The mean indices for plaque, calculus, gingiva, and bleeding were shown to be very low at the 1-year evaluation. The scores are comparable to those reported by Guljé and colleagues[32] and Meijer and colleagues[33] in which the same criteria were used and in which also OsseoSpeed 4.0 S dental implants and Straumann Standard SLA implants were used although applied in the mandible. The mean probing depth was 4.3 mm at the 1-year evaluation period in both groups. This depth is not much different as reported in other studies and is accompanied with healthy peri-implant soft tissues. The strict oral hygiene regime to which patients were subjected to resulted in healthy peri-implant tissues. Although compared with results of patients who are edentulous in both jaws, it seems that the presence of natural antagonistic teeth does not have a negative influence on the outcome of implants. It must be noted, however, that patients could only be included in the study if healthy natural antagonistic teeth and a healthy periodontium were present.

TABLE 6 Mean Score of Functional Complaints about Upper Denture (Possible Range 0–3), Mean Scores of Chewing Ability of Soft, Tough, and Hard Food (Possible Range 0–2), Overall Satisfaction Score (Possible Range 1–10) 1 Year after Treatment of Participants with Complete or Incomplete Natural Dentition in the Mandible, Six Occluding Pairs or Less Than Six Occluding Pairs, a Bilaterally Balanced Occlusion or Not a Bilaterally Balanced Occlusion, and Possible Significant Differences of the Combined Study Groups with Anterior Implants and Posterior Implants

	State of Natural Dentition in the Lower Jaw			Number of Occluding Pairs			Occlusal Concept		
	Complete ($n = 16$)	Incomplete ($n = 34$)	Significance	Six ($n = 27$)	Less Than Six ($n = 23$)	Significance	Balanced ($n = 5$)	Not Balanced ($n = 45$)	Significance
Functional complaints about upper denture (SD)	0.2 (0.2)	0.2 (0.1)	ns	0.1 (0.1)	0.2 (0.1)	ns	0.2 (0.1)	0.2 (0.1)	ns
Soft food (SD)	0.0 (0.0)	0.0 (0.0)	ns	0.0 (0.0)	0.0 (0.0)	ns	0.0 (0.0)	0.0 (0.0)	ns
Tough food (SD)	0.1 (0.6)	0.1 (0.6)	ns	0.1 (0.1)	0.0 (0.0)	ns	0.1 (0.1)	0.1 (0.2)	ns
Hard food (SD)	0.1 (0.2)	0.3 (0.5)	ns	0.3 (0.1)	0.2 (0.1)	ns	0.4 (0.5)	0.2 (0.4)	ns
Overall satisfaction score (SD)	8.7 (0.9)	8.8 (0.9)	ns	9.0 (0.9)	8.5 (0.8)	ns	9.0 (0.7)	8.7 (0.9)	ns

ns = not significant.

The mean scores of the two questionnaires and the overall satisfaction score improved significantly from before implant treatment to the 1-year evaluation in both groups (see Table 4). Studies on patients' satisfaction with maxillary overdentures, evaluated with validated questionnaires, are not known. So, results of the present study cannot be compared with other studies on implant-supported maxillary overdentures, although it has been mentioned in general terms in other studies that patients' satisfaction is high.[10,34] The same questions as used in the current study were asked for mandibular implant overdentures and showed comparable results.[26,35] It seems that with maxillary overdenture treatment, comparable successful results can be achieved as with mandibular overdenture treatment. There were no significant differences in patients' satisfaction between the anterior and posterior groups at the post-treatment evaluation period (see Table 5). In the retrospective study of Krennmair and colleagues,[10] it was stated that after a mean evaluation period of 42 months no significant differences in subjective satisfaction scores could be found between a group with implants in the anterior maxillary region and a group with implants in the posterior maxillary region. Patients seem to be equally satisfied, irrespective of the region where the implants are placed. The reason could be that the overdenture is supported by a bar on six implants in both regions, which gives comparable stability. It is striking that no significant differences in patients' satisfaction were noted with respect to the number of antagonistic teeth, the number of occluding pairs, and the presence or absence of a bilaterally balanced occlusion (see Table 6). It could be that the impact of a stable denture, with good support and retention, has such a high impact on satisfaction that other factors are rated as minor inconveniences. It does not seem to be of influence if there are less remaining antagonistic teeth, a lower number of occluding pairs, and the absence of a bilaterally balanced occlusion. A longer follow-up period is, however, needed to confirm the findings in this short-term study.

This treatment strategy of first exploring the anterior maxillary region for implant placement reduces treatment time and morbidity for a number of patients. Next to this, the insertion of four implants could be analyzed for reasons of further cost-effectiveness.

From this 1-year study, it is concluded that six dental implants placed in either the anterior region or the posterior region of the edentulous maxilla,

connected with a bar, and opposed to natural antagonistic teeth in the mandible supply a proper base for the support of an overdenture.

REFERENCES

1. Van Waas MAJ. The influence of clinical variables on patients' satisfaction with complete dentures. J Prosthet Dent 1990; 63:307–310.
2. Raghoebar GM, Meijer HJ, Stellingsma K, Vissink A. Addressing the atrophied mandible: a proposal for a treatment approach involving endosseous implants. Int J Oral Maxillofac Implants 2011; 26:607–617.
3. Thomason JM, Kelly SA, Bendkowski A, Ellis JS. Two implant retained overdentures: a review of the literature supporting the McGill and York consensus statements. J Dent 2012; 40:22–34.
4. Meijer HJA, Raghoebar GM, Batenburg RHK, Visser A, Vissink A. Mandibular overdentures supported by two or four endosseous implants: a 10-year clinical trial. Clin Oral Implants Res 2009; 20:722–728.
5. Vercruyssen M, Marcelis K, Coucke W, Naert I, Quirynen M. Long-term, retrospective evaluation (implant and patient-centered outcome) of the two-implants-supported overdenture in the mandible. Part 1: survival rate. Clin Oral Implants Res 2010; 21:357–365.
6. Sadowsky SJ. Treatment consideration for maxillary implant overdentures: a systematic review. J Prosthet Dent 2007; 97:340–348.
7. Slot W, Raghoebar GM, Vissink A, Huddleston Slater JJ, Meijer HJ. A systematic review of implant-supported maxillary overdentures after a mean observation period of at least 1 year. J Clin Periodontol 2010; 37:98–110.
8. Andreiotelli M, Att W, Strub JR. Prosthodontic complications with implant overdentures: a systematic literature review. Int J Prosthodont 2010; 23:195–203.
9. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. Eur J Oral Sci 1998; 106:527–551.
10. Krennmair G, Krainhöfner M, Piehslinger E. Implant-supported maxillary overdentures retained with milled bars: maxillary anterior versus maxillary posterior concept – a retrospective study. Int J Oral Maxillofac Implants 2008; 23:343–352.
11. Sanna A, Nuytens P, Naert I, Quirynen M. Successful outcome of splinted implants supporting a "planned" maxillary overdenture: a retrospective evaluation and comparison with fixed full dental prostheses. Clin Oral Implants Res 2009; 20:406–413.
12. Ohkubo C, Baek KW. Does the presence of antagonistic remaining teeth affect implant overdenture success? A systematic review. J Oral Rehabil 2010; 37:306–312.
13. Chan MF, Howell RA, Cawood JI. Prosthetic rehabilitation of the atrophic maxilla using pre-implant surgery and endosseous implants. Br Dent J 1996; 181:51–58.
14. Åstrand P, Nord PG, Brånemark PI. Titanium implants and onlay bone graft to the atrophic maxilla: a 3-year longitudinal study. Int J Oral Maxillofac Surg 1996; 25:25–29.
15. Kahnberg KE, Nilsson P, Rasmusson L. Le Fort I osteotomy with interpositional bone grafts and implants for rehabilitation of the severely resorbed maxilla: a 2-stage procedure. Int J Oral Maxillofac Implants 1999; 14:571–578.
16. Carlsson GE. Dental occlusion: modern concepts and their application in implant prosthodontics. Odontology 2009; 97:8–17.
17. Taylor TD, Belser U, Merickske-Stern R. Prosthodontic considerations. Clin Oral Implants Res 2000; 11 (Suppl): 101–107.
18. Smeets EC, De Jong KJ, Abraham-Inpijn L. Detecting the medically compromised patient in dentistry by means of the medical risk-related history. A survey of 29.424 dental patients in The Netherlands. Prev Med 1998; 27:530–535.
19. Raghoebar GM, Vissink A, Reintsema H, Batenburg RH. Bone grafting of the floor of the maxillary sinus for the placement of endosseous implants. Br J Oral Maxillofac Surg 1997; 35:119–125.
20. Raghoebar GM, Timmenga NM, Reintsema H, Stegenga B, Vissink A. Maxillary bone grafting for the insertion of endosseous implants: results after 12–124 months. Clin Oral Implants Res 2001; 12:279–286.
21. Slot W, Raghoebar GM, Van Dijk G, Meijer HJA. Attachment of clips in a bar-retained maxillary implant overdenture: a clinical report. J Prosthet Dent 2012. (In press)
22. Meijndert L, Meijer HJA, Raghoebar GM, Vissink A. A technique for standardized evaluation of soft and hard peri-implant tissues in partially edentulous patients. J Periodontol 2004; 75:646–651.
23. Mombelli A, Van Oosten MAC, Schürch E, Lang N. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol 1987; 2:145–151.
24. Löe H, Silness J. Periodontal disease in pregnancy. II: correlation between oral hygiene and periodontal condition. Acta Odontol Scand 1963; 21:533–551.
25. Vervoorn JM, Duinkerke ASH, Luteijn F, Van Der Poel ACM. Assessment of denture satisfaction. Community Dent Oral Epidemiol 1988; 16:364–367.
26. Stellingsma K, Slagter AP, Stegenga B, Raghoebar GM, Meijer HJA. Masticatory function in patients with an extremely resorbed mandible restored with mandibular implant-retained overdentures: comparison of three types of treatment protocols. J Oral Rehabil 2005; 32:403–410.
27. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants:

a review and proposed criteria for success. Int J Oral Maxillofac Implants 1986; 1:11–25.

28. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981; 10:387–416.
29. Van de Velde T, Collaert B, Sennerby L, De Bruyn H. Effect of implant design on preservation of marginal bone in the mandible. Clin Implant Dent Relat Res 2010; 12:134–141.
30. Hermann JS, Cochran DL, Nummikoski PV, Buser D. Crestal bone changes around titanium implants. A radiographic evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. J Periodontol 1997; 68:1117–1130.
31. Broggini N, McManus LM, Hermann JS, et al. Persistent acute inflammation at the implant-abutment interface. J Dent Res 2003; 82:232–237.
32. Guljé F, Raghoebar GM, Ter Meulen JW, Vissink A, Meijer HJA. Mandibular overdentures supported by 6-mm dental implants: a 1-year prospective cohort study. Clin Implant Dent Relat Res 2011. DOI: 10.1111/j.1708-8208.2011.00358.x. [Epub ahead of print].
33. Meijer HJA, Raghoebar GM, Batenburg RH, Vissink A. Mandibular overdentures supported by two Brånemark, IMZ or ITI implants: a ten-year prospective randomized study. J Clin Periodontol 2009; 36:799–806.
34. Visser A, Raghoebar GM, Meijer HJ, Vissink A. Implant-retained maxillary overdentures on milled bar suprastructures: a 10-year follow-up of surgical and prosthetic care and aftercare. Int J Prosthodont 2009; 22:181–192.
35. Raghoebar GM, Meijer HJA, Van 't Hof MA, Stegenga B, Vissink A. A randomized prospective clinical trial on the effectiveness of three treatment modalities for patients with lower denture problems. A 10 year follow-up study on patient satisfaction. Int J Oral Maxillofac Surg 2003; 32:498–503.