Literature review and clinical procedures with a twelve-month follow-up

Immediate and Delayed "All-on-Six" Rehabilitation of the Atrophic Maxilla with Tilted Implants

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State-of-the-art implant treatment provides simple and individualized implant-supported restorations while reducing the number of surgical sessions and optimizing both function and aesthetics. But this requires a successful cooperation between the surgeon, the prosthodontist and the dental technician and a clear focus on the prosthetic rehabilitation.

A careful and accurate diagnosis and precise planning of the prosthetic design render the rehabilitation of the edentulous patient predictable. Implantological and prosthetic treatment alternatives for the completely edentulous jaw differ between the maxilla and the mandible [1,2] (Tab. 1). Fixed implant-supported hybrid restorations as described by *Brånemark* require the insertion of four to six parallelized implants in the intraforaminal area. The literature reports implant success rates of 95 percent and prosthetic success rates of 100 percent over ten to 15 years [3,4].

Fixed hybrid dentures require a bilateral posterior cantilever design that – depending on the anatomy of the anterior alveolar ridge (round or flat) and on the position of the genial foramen or the maxillary sinus – may reach or exceed a critical length of 15 mm and may impart serious loads on the implants, the implant/denture connection and the peri-implant bone [5].

Implant-supported fixed restorations for the edentulous jaw are often subject to anatomic limitations in the posterior regions, limitations that are presented by the mandibular canal and the genial foramen (mandible) or the maxillary sinus (maxilla). Posterior tilting of the distal implants reduces the length of the cantilever segments, allowing it to be lengthened without any sinus lift, bone augmentation or transposition of the mandibular nerve [6,7]. The tilting technique has three advantages:

1. Added distal implant support with consequent shortening of the distal extension segment,
2. Increased implant length, and
3. Implant retention in the dense bone adjacent to the anterior sinus wall along with improved primary stability [8,9].

From a biomechanical point of view, the distalization of the implant platform reduces the moments of force and improves load distribution.

The insertion of six implants in the anterior maxilla, with the two distalmost implants tilted distally along the mesial wall of the maxillary sinus, allows the construction of a fixed hybrid prosthesis called "Marius bridge" by *Fortin et al.* [8], after the first patient rehabilitated with this type of fixed restoration. It combines the patient comfort of a fixed prosthesis with a partial reconstruction of the hard-tissue and soft-tissue anatomy without bone grafting [8]. The authors report 97 percent survival rates for the implants and 100 percent survival rates for the prosthesis [9].

While more and more scientific evidence indicates that immediate loading offers predictable results and achieves osseointegration in the mandible [10-12], the maxilla, because of its anatomy and morphology, historically causes problems in this respect [13,14]. Rigid implant splinting protects the bone-implant interface from functional overload and prevents

Tab. 1 Alternative implant-supported prosthetic rehabilitations of the edentulous jaws.

edentulous mandible	edentulous maxilla
2 implants & overdenture	4 implants & overdenture
4–5 implants & fixed/removable hybrid implant-supported prosthesis	6 implants & fixed/removable hybrid implant-supported prosthesis
6–8 implants & fixed implant-supported prosthesis	6–10 implants & fixed implant-supported prosthesis

(n)	author	follow-up	mandible	maxilla	I / D	success				bone loss		BIC	
						upright	tilted	prosthesis	failure	BIC	U / T	I	D
23	Grunder, 2001	2 y		x	I	87,50%		100%		similar			
28	Testori et al., 2001	4 mo	x		I							78-85%	
8	Fortin et al., 2002	5 y		x	I/D	97%		100%	early / 3y				
27	Testori et al., 2002	2 mo	x		I/D							64,20%	38,90%
10	Testori et al., 2003	48 mo	x		I	98,90%		100%	3 we	similar			
12	Testori et al., 2004	12-60 mo	x		I	99,40%		100%		similar			
11	Testori et al., 2004	8-65 mo	x		I	97,40%		100%	2 mo	similar			
21	Balshi et al., 2005	1-5 y		x	I	99%		100%					
24	Calandriello & Tomatis, 2005	1 y		x	I	96,70%	96,7%	100%		similar			
20	Degidi et al., 2005	5 y		x	I	98%		100%	6 mo				
22	Ostman et al., 2005	12 mo		x	I/D	99,2% / 100%		100%		similar			
29	Romanos et al., 2005	2-10 mo	x	x	I							66,805%	
26	Cannizzaro et al., 2007	12 mo		x - post-ex	I	96,30%		100%					
18	Capelli et al., 2007	40 mo		x	I	97,59%		100%	12-18 mo		similar		
19	Daverio et al., 2007	12 mo		x	I/D	98,07% / 100%	100%	100%	2 mo		similar		
25	Testori et al., 2008	12 mo		x	I	90,80%		100%	12-18 mo		similar		

I = immediate loading
D = delayed loading
U = upright implant
T = tilted implant
y = year/s
mo = month/s
we = week/s

Tab. 2 Schematic revision of the literature references in the text (n) about immediate loading procedures and tilted implants displaying implant and prosthetic success, peri-implant marginal bone resorption and bone-implant-contact (BIC).

implant micromovement, facilitating predictable immediate loading in the maxilla [15].

Immediate loading requires precise presurgical planning, a suitable device to transfer the prosthetic design from the cast to the radiograph, an appropriate surgical procedure and finally the use of a temporary restoration [16]. The cervical emergence profile of the prosthesis is the critical element. The space defined by the tooth crowns/implants/abutments/residual ridge determines the choice of the restorative solution. Immediate placement of a provisional prosthesis directly conditions the peri-implant marginal tissue for the desired emergence profile as early as during the first healing phase [17]. Other advantages of the immediate loading protocol include shorter treatment times, less postsurgical discomfort and the immediate rehabilitation of the masticatory function as well as of phonetic and aesthetic aspects.

Immediate loading of the edentulous maxilla shows 87.5 to 98.9 percent implant success and 100 percent prosthetic success, both with tilted and non-tilted implants [18-25] and post-extraction (immediate) implants [26] (Tab. 2). Implant failures are above all early failures [10,11,12,19]. The resorption of the marginal bone around the implants is similar for immediate loading and delayed loading [10,11,12,22, 23,24,25] and for tilted vs. non-tilted implants [18,19, 24,25]. Histological examination shows bone-implant contact (BIC) of 64.2 percent and 85 percent after two and four months of immediate loading compared to 38.9 percent after two months of delayed loading [27-29] (see Tab. 2).

	patient A	patient B
anamnesis	phobic patient diabetes I	smoking (n>10) osteoporosis – oral bisphosphonate therapy
clinical diagnostic phase (Figs. 1, 2)	skeletal and soft tissue analysis inter-maxillary relation (1a) residual tooth elements incongruent fixed prosthesis (2a)	skeletal and soft tissue analysis inter-maxillary relation (1b) edentulous maxilla – reduced resorption (2b) removable total prosthesis
instrumental diagnostic phase (Figs. 3, 4, 5)	cast model – facebow verification inter-maxillary relation articulator set-up (3a) provisional prosthesis -- surgical device (4a) radiographic analysis (5a)	cast model – facebow registration inter-maxillary relation articulator wax-up (3b) provisional prosthesis (4b) esthetic-functional verification surgical device radiographic analysis (5b)
I surgical phase (Figs. 6, 7, 8 9b, 10b, 11b)	dental extractions immediate – delayed implants (6a, 7a) --	-- delayed implants (6b, 7b, 8b, 9b, 10b, 11b)
II surgical phase (Fig. 12b)		implant exposure & creation attached gingiva (12b)
I prosthetic phase (Figs. 9a, 10, 11a)	screwed provisional prosthesis (8a, 9a) immediate loading procedure (10a, 11a)	screwed provisional prosthesis delayed loading procedure
II prosthetic phase (Figs. 12a, 13, 14, 15, 16, 17)	cemented definitive prosthesis (12a, 13a, 14a, 15a, 16a, 17a)	cemented definitive prosthesis (13b, 14b, 15b, 16b, 17b)
maintenance phase & follow-up	hygiene instruction & motivation individualized recall	

Tab. 3 Schematic representation of the two different clinical procedures: immediate loading ***(patient A)*** *and delayed loading* ***(patient B),*** *and their iconographic correspondence.*

The aim of the present paper is to clinically examine two different "All-on-Six" rehabilitation approaches for moderately atrophic maxillae using tilted implants, to compare treatment durations and immediate vs. delayed loading and to evaluate implant success rates and marginal bone resorption.

Materials and methods

Two different clinical approaches were used (Tab. 3): for patient A, immediate post-extractive implants followed by immediate loading; for patient B, a traditional protocol with delayed implant insertion at the first surgical stage and implant uncovering at the second surgical stage followed by delayed loading. The patients each received six Camlog Root-Line implants (Camlog Biotechnologies AG, Switzerland). A careful anamnesis as well as the patient's wishes both justified the two different approaches. Surgery on patient A, who presented with phobias, occurred in conscious sedation with the support of an anaesthetist. The fact that oral bisphosphonates (alendronate, 1 tablet/week) had been taken by patient B for the preceding two years precluded sophisticated regenerative techniques, even in the absence of solid scientific evidence. A scrupulous clinical and instrumental analysis (Figs. 1 to 4) gave legitimation to a precision design for an implant-supported prosthetic rehabilitation and defined the surgical and technical aspects.

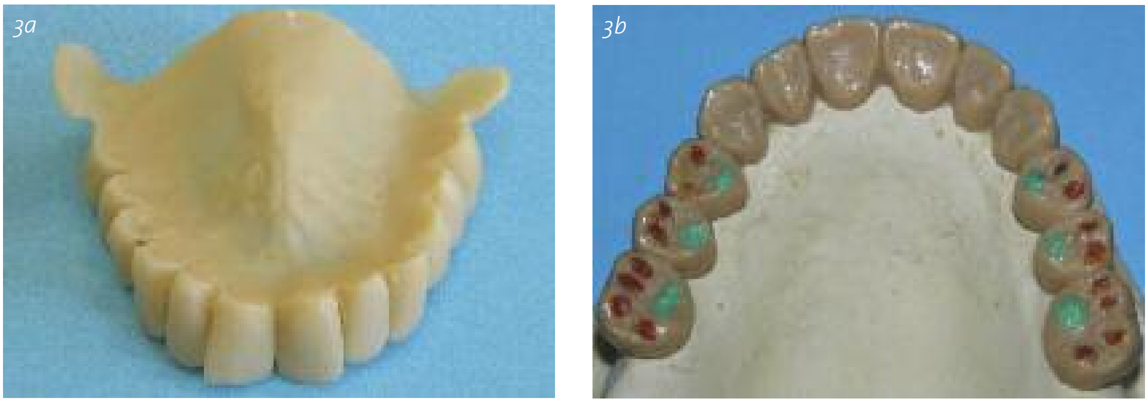
The indication for a fixed rehabilitation cemented on custom abutments for both patients was justified by the intermaxillary relation and by adequate support by the oral and perioral soft tissues (see Figs. 1a and b). The bone volume of surgical interest was outlined by the lateral wall of the nose, by the anterior recess of the maxillary sinus and by the residual alveolar ridge. Significant bone resorption at the premolar level was not a part of this clinical indication. The tilted implant had to be of maximum length to exploit the whole length of the mesial wall of the maxillary sinus up to the lateral wall of the nose. The planning for the bilateral tilted implants was followed by the planning of the intermediate ones, respecting the implant axis and the inter-implant spaces according to the prosthetic design.

The surgical phase began once the superstructure design had been precisely defined and a surgical stent was realized (Figs. 3 and 4).

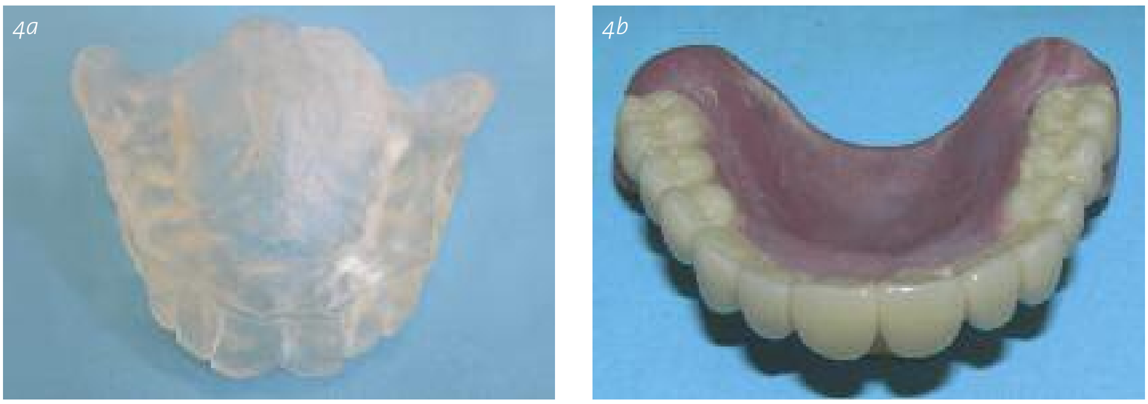
Figs. 1a and b
Clinical analysis,
frontal (a) and
lateral (b) view.

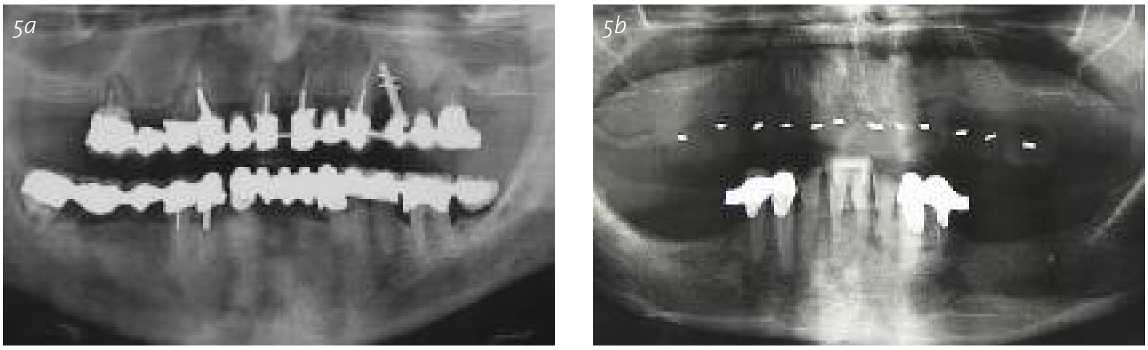
Figs. 2a and b
Clinical analysis,
occlusal view.

Figs. 3a and b
Set-up (b) and
wax-up (a).

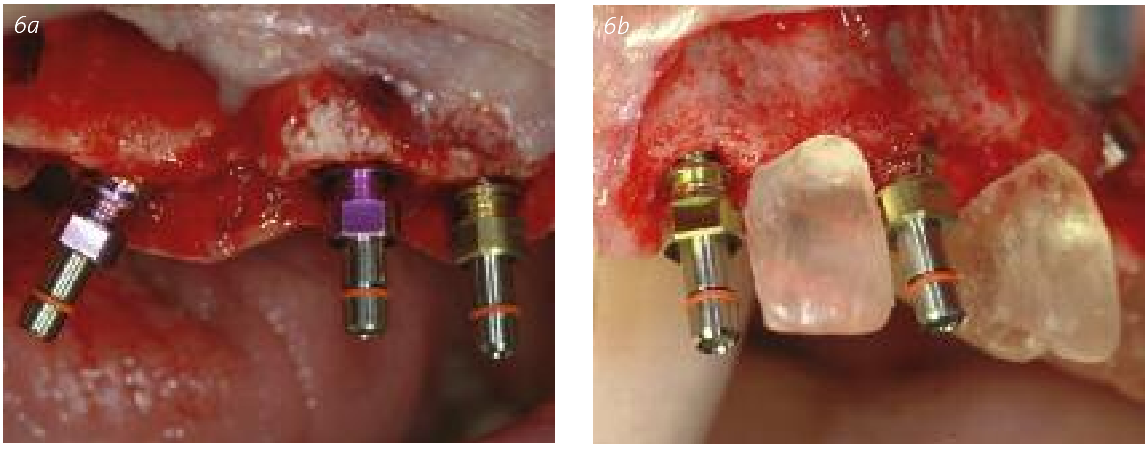


Figs. 4a and b
Surgical device (a)
and provisional
prosthesis (b).

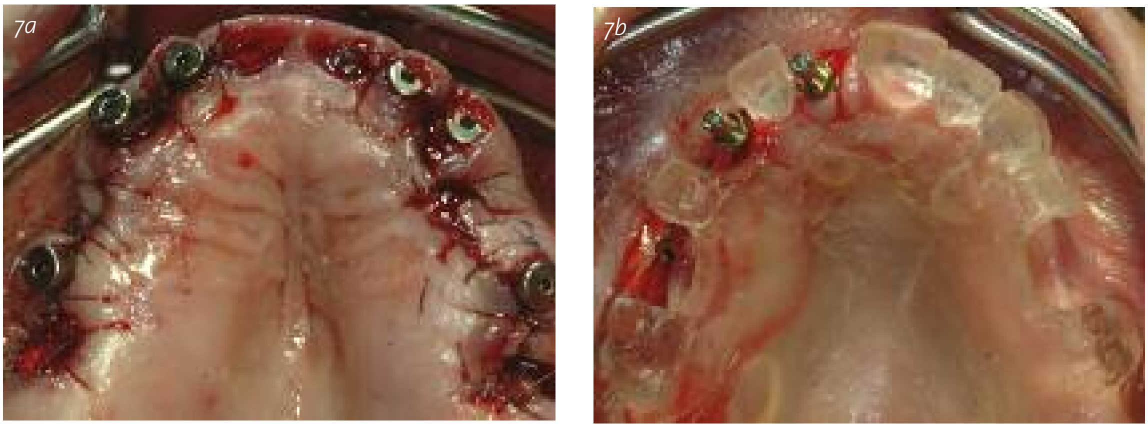




Figs. 5a and b Radiographic analysis (a) with surgical stent (b).



Figs. 6a and b Tilted implant placed at height of the premolar (a) and upright implants placed in the premaxilla (b).



Figs. 7a and b Bilateral surgical approach.

The radiographic and CT analyses facilitated exact surgical planning (Fig. 5). The bilateral surgical approach, where possible, is more conservative for the tissues and less traumatic for the patient. Raising a full-thickness flap through a crestal incision and mesial and distal releases expose the area of the maxillary sinus. A diagnostic antrostomy of the maxillary sinus, extended mesially adjacent to the anterior sinus wall, may help identify and control the correct implant location. According to the prosthetic design, the emergence of the implant should be placed in the second premolar area, with a 30 to 35 degree inclination from the vertical upright plane (Fig. 6a).

Once the first tilted distal implant was placed, the surgical procedure continued according to the prosthetic design with the placement of the implant in the central or lateral incisal area, prosthetically guided with the help of the surgical stent (Figs. 6b, 7b and 8b). The intermediate implant is generally placed in the canine region. Root-form implants are particularly suitable for this kind of placement thanks to their geometry. The reduced apical shape of these implants allows their correct placement, avoiding contacts between them and bone perforations in the restricted apical zone of the maxillary base. Once the implant placement is completed, the sinus antrostomy can be sealed with collagen sponges without invading the sinus cavity in case of accidental perforation. Procedure B ends with suturing and a radiographic check (Figs. 9b, 10b and 11b).

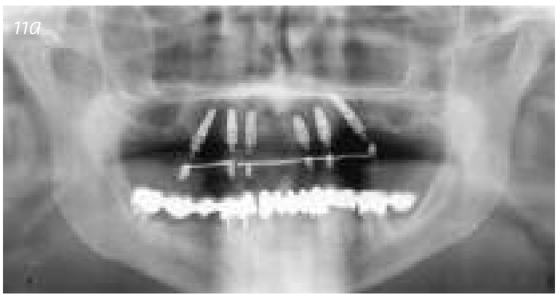
The immediate-loading procedure A required recording the implant position immediately after placement using a custom stent/impression tray (Fig. 8a) that

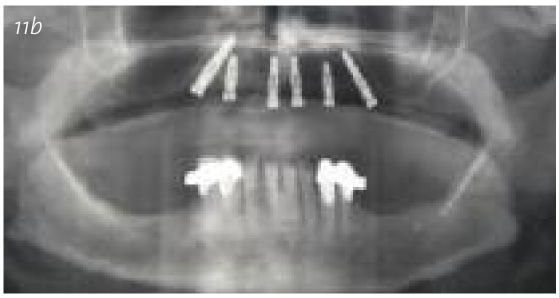
Figs. 8a and b Registration of the implant position (a) and control of the implant surgical stent (b).

Figs. 9a and b Provisional prosthesis (a) and sutures (b).

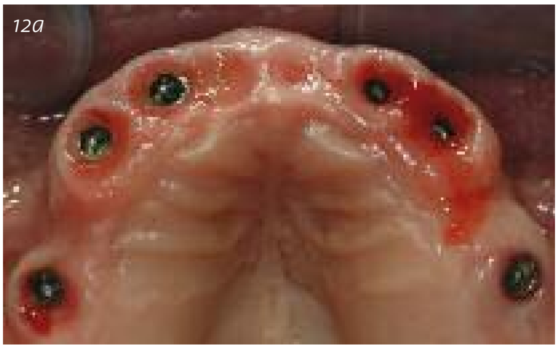
Figs. 10a and b Positioning of the screwed provisional prosthesis (a) and suture removal (b).

Figs. 11a and b Radiographic control after surgery.





allows the assembly of the cast directly in the articulator and provisionalization by inserting abutments into the previously completed provisional full-arch restoration (Fig. 9a). The placement of the provisional screw-retained prosthesis four hours after surgery ended with the radiographic check (Figs. 10a and 11a).



Figs. 12a and b Healing and maturation of the soft tissue (a) and implant exposure (b).

Figs. 13a and b Copying placement (a) and impression-taking (b).

Once the implant had osseointegrated, procedure B required a second surgical phase to uncover the implants according to the standard rules of periodontology (Fig. 12b), followed by healing and maturation of the soft tissue aided by placement of a fixed temporary prosthesis that can be screw-retained or cemented depending on aesthetic requirements and the necessities of tissue conditioning.

Procedure A required the removal of the temporary restoration and an impression (Figs. 12a and 13a). The fixed prostheses (A and B) were cemented on custom abutments (Figs. 14 to 16).

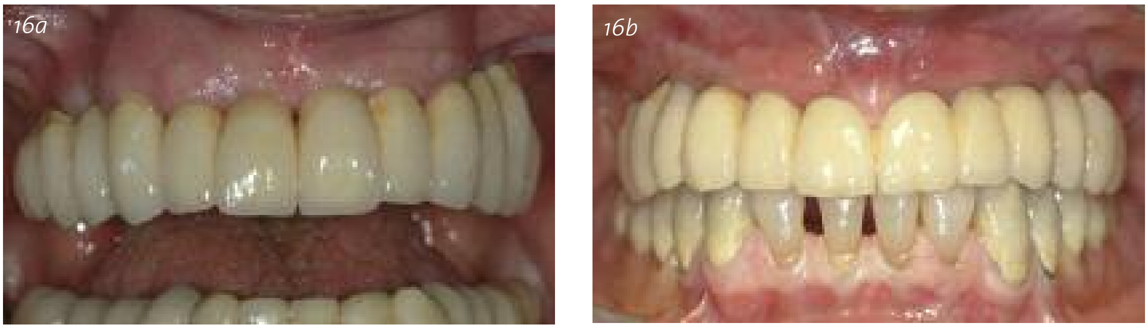
The correct placement of the full-arch restorations, the degree of osseointegration and the peri-implant marginal bone resorption were periodically checked clinically and radiographically (Fig. 17). The marginal bone resorption is measured radiographically on orthopantomographs using a software-integrated and appropriately calibrated digital measurement program at the implant platform level, mesially and distally, at the times of implant placement, impression-taking, placement of the final prosthesis and during recalls (every six to twelve months).

Results

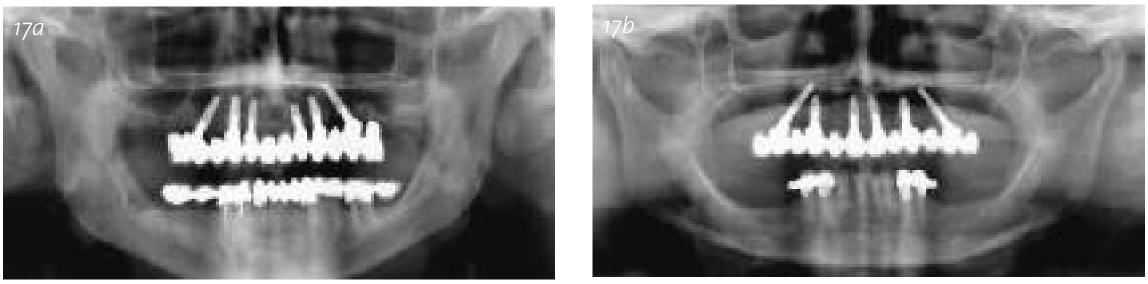
During the twelve-month follow-up period, no implant failures and no prosthetic complications were recorded. Both patients stated their complete satisfaction with their individual treatment options, methods and timing and with the functional and aesthetic result.

Figs. 14a and b Positioning of the definitive individualized abutments, frontal view (a) and occlusal view (b).

Figs. 15a and b Final prosthesis in situ, occlusal view.



Figs. 16a and b Final prosthesis in situ, frontal view.



Figs. 17a and b Radiographic outcome.

Marginal bone resorption, measured mesially and distally on each implant, was within the physiological range of 0 to 1.4 mm, seemingly increasing from implant placement to impression-taking, but then decreasing and stabilizing over time, becoming less pronounced around tilted than around non-tilted implants, both with immediate and delayed loading. This agrees well with the data obtained from the literature. These preliminary results need more clinical confirmation and further investigation to achieve statistically significant results for scientific evidence.

Discussion

The rates of implant and prosthetic success recorded in the literature review [8,18,19] and in the clinical cases have shown that (1) the inclination of the implant axis relative to the surrounding bone and the occlusal plane is not a determinant for implant or prosthetic failure and that (2) implant tilting is not a determinant for marginal bone resorption. Implant treatment planning for the residual bone of the premaxilla cannot ignore the parameters of prosthetically guided implantology. An accurate diagnosis must precede the assembly of the casts in the articulator using a facebow and the creation of a custom set-up. A correct three-dimensional implant placement has to establish a suitable emergence profile of the implant platform into the prosthetic arch and appropriate tilting of the implant axis relative to the occlusal plane. The results from the literature (see Tab. 2) and from the clinical cases confirm the predictability of implant-supported fixed restorations for the edentulous maxilla with distally tilted implants, with both immediate and delayed loading, reducing the need for bone augmentation and post-surgery discomfort and shortening treatment times. Peri-implant measurements show a level of bone resorption similar to that described in the literature, and overlapping shapes, both in tilted and non-tilted implants and in immediate and delayed loading. Peri-implant bone resorption is a physiological process that decreases with time and also depends on the individual response of the organism and on the patient's habits and oral hygiene. Regular follow-ups must include customized maintenance programs and standard checks of the clinical and radiographic implant parameters.

Conclusions

The literature review and the clinical cases define a suitable protocol for an implant-supported rehabilitation of the completely edentulous maxilla. The placement of six implants in the pre-maxilla, two of them tilted distally along the maxillary sinus anterior wall, eliminates problems of bone atrophy in the posterior areas and renders advanced surgery with tissue grafts unnecessary, allowing the rehabilitation of the masticatory and phonetic function and aesthetics using a fixed implant-supported prosthesis. Literature data on tilted and non-tilted implants underline the overlapping of peri-implant resorption of the marginal bone, refuting the hypothesis that tilted implants are more prone to failure because of their angle to the bone crest, to the occlusal plane and to the main direction of functional load [6,7,18,19]. ■

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