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Immediate loading of 'All-on-4' maxillary prostheses using trans-sinus tilted implants without sinus bone grafting: a retrospective study reporting the 3-year outcome

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Key words *All-on-4, atrophic maxillae, complete edentulism, dental implants, trans-sinus*

Purpose: To report the outcome of trans-sinus tilted implants for the rehabilitation of the complete edentulous atrophic maxilla using the All-on-4 concept with immediate loading.

Materials and methods: This retrospective clinical study included 70 patients treated with 280 implants (Nobel Biocare), 83 of which were trans-sinus implants supporting 70 prostheses. The inclusion criteria were need of maxillary complete edentulous rehabilitation without enough bone height posterior to the canines to anchor the implants. The trans-sinus implant head was anchored on the bone available just posterior to the anterior sinus wall and inferior to the sinus floor. The trans-sinus implant body was inside the sinus, and its apex anchored in the bone between the anterior sinus wall and the nasal cortical. The nasal cortical was used, if necessary, to achieve a double bicortical anchorage. Implants were immediately loaded with cross-arch fixed prostheses. Follow-up examinations were performed after 10 days, 2, 4 and 6 months, and 1, 2 and 3 years. Radiographic evaluations were performed after 1 and 3 years of function. Outcome measures were success of the prostheses, success of the implants, complications, peri-implant marginal bone levels, and aesthetic and functional complaints. Survival was calculated at implant level and using the patient as the unit of analysis (first implant failure in any given patient) using life-table analysis.

Results: Seven patients dropped out of the study. Three trans-sinus tilted implants were lost in 3 patients, giving a cumulative survival rate of 95.7% and 96.4% at patient and implant level, respectively. One conventional tilted implant was lost in 1 patient (one of the patients that lost a trans-sinus tilted implant), giving a cumulative survival rate of 98.1%. One straight implant was lost in one patient (a second patient that lost a trans-sinus implant), giving a cumulative survival rate of 98.6% and 99.3% at patient and implant level, respectively. The survival rate of prostheses was 100%. Sinusitis occurred in 2 patients (2.9%). The marginal bone resorption was on average (standard deviation), 0.96 mm (0.62 mm) and 1.14 mm (0.74 mm) for the trans-sinus tilted implants, 0.89 mm (0.54 mm) and 1.06 mm (0.71 mm) for the conventional tilted implants, and 0.62 mm (0.35 mm) and 1.15 mm (0.51 mm) for the straight implants after 1 and 3 years of follow-up, respectively.

Conclusions: The high survival rate registered at patient and implant level indicates that the outcome of immediately loaded trans-sinus implants for the rehabilitation of edentulous atrophic maxillae to avoid sinus lift procedures is a viable treatment in the short- and medium term. Future studies should focus on the long-term outcome of this rehabilitation modality.

Conflict-of-interest statement: *Professor Paulo Maló serves as a consultant for Nobel Biocare.*

Table 1 Type of implant and distribution.

Type of implants	Implant position												Total
	16	15	14	13	12	11	21	22	23	24	25	26	
Trans-sinus tilted implants	0	43	0	0	0	0	0	0	0	0	34	1	78
Conventional tilted implants	1	25	1	0	0	0	0	0	0	4	28	5	64
Conventional axial implants	0	0	0	1	36	33	35	34	1	0	0	0	140
Total	1	68	1	1	36	33	35	34	1	4	60	6	*280*

■ Introduction

The rehabilitation of the atrophic maxilla can represent a challenge when the pneumatisation of the sinus causes a major limitation for implant insertion in the posterior maxilla, especially when immediate function is implemented[1]. To overcome such a limitation, there are several alternatives that can be chosen, ranging from the use of short implants, bone grafting or zygomatic implants[1-19]. Recently, a combination of techniques was documented, placing implants inserted trans-sinus simultaneously with bone morphogenetic protein 2 sinus floor grafting, achieving a 94.8% success rate after 1 year[19].

The use of tilted implants for the rehabilitation of the atrophic maxilla has been documented in the literature with good short-, medium- and long-term outcomes[20-22]. Specifically for the rehabilitation of the atrophic maxilla, the use of 4 implants inserted in immediate function (2 implants tilted distally up to 45 degrees and 2 implants inserted in the axial position; All-on-4™, Nobel Biocare, Gothenburg, Sweden) demonstrated good long-term outcomes[23]. The atrophy of the maxilla may compromise the insertion of a conventional tilted implant. Trans-sinus implants may be used when the insertion of conventional tilted implants is not possible[23], before considering the use of zygomatic implants[5,6] or bone grafting procedures[2-4].

The aim of this study was to evaluate the use of trans-sinus tilted implants without simultaneous bone-grafting or sinus-lift procedures for the rehabilitation of the complete edentulous atrophic maxilla using the All-on-4 concept (4 immediately loaded implants).

■ Material and methods

This article was written following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines[24]. This clinical study was performed in a private clinic, Malo Clinic, in Lisbon, Portugal, and was approved by an independent ethical committee (Ethical Committee for Health, Lisbon, Portugal; Authorization no. 013/2010).

Seventy patients (29 males and 41 females; mean age 54 years; range 35–81 years) were consecutively included from February 2005 to February 2010, provided that they met the inclusion criteria. Twenty-nine patients had systemic diseases: diabetes (n = 3), cardiovascular problems (n = 23), thyroid diseases (n = 2), hepatitis (n = 3) and HIV (n = 1). Two patients presented more than one condition. Twenty-two patients were heavy bruxers and 19 patients were smokers. A total of 280 implants (Nobel Biocare) were inserted (Table 1). Of these, 83 were trans-sinus implants: 10 mm (n = 1), 13 mm (n = 3), 15 mm (n = 11) and 18 mm (n = 68) long. A total of 57 were conventional tilted implants: 13 mm (n = 2), 15 mm (n = 17) and 18 mm (n = 38) long. In total, 140 were standard straight implants: 8.5 mm (n = 6), 10 mm (n = 24), 11.5 mm (n = 31), 13 mm (n = 45) and 15 mm (n = 29) long. The implant models were NobelSpeedy Replace (Nobel Biocare; 10 mm [n = 2], 11.5 mm [n = 1]) and NobelSpeedy Shorty (Nobel Biocare; 7 mm [n = 2]).

On the opposing jaw, there were implant-supported prostheses (28 patients), natural teeth (16 patients), a combination of both (25 patients) and a removable prosthesis (1 patient).

Inclusion and exclusion criteria

The inclusion criteria were patients in need of a maxillary complete edentulous rehabilitation without having enough bone height posterior to the canines to anchor and stabilise the implants, as reflected in the following anatomical criteria (Figure 1):

- Presence of a minimum of 3 mm of height available under the sinus floor to anchor the implant's head
- An anterior sinus wall that, due to its curvature, did not allow placing a tilted implant through the standard protocol using between a 30 and 45 degree angulation fully inside the bone
- And/or the inferior corner of the anterior wall of the sinus positioned anterior to the first premolar.

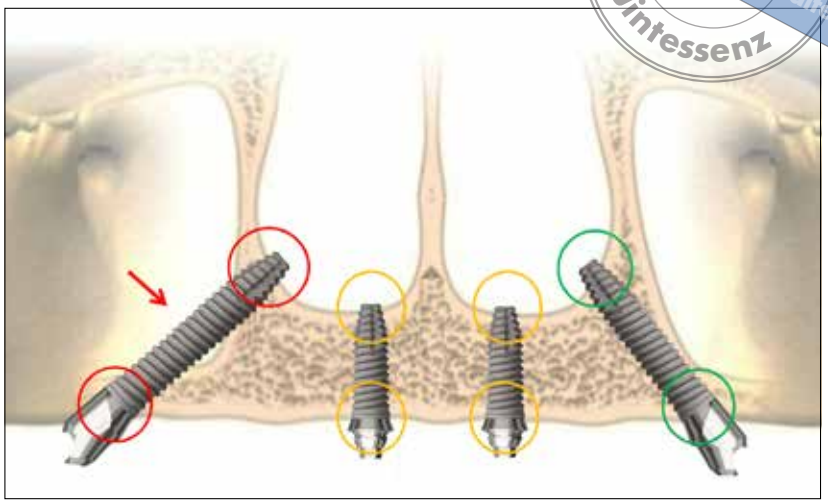

Fig 1 Illustration representing an implant inserted trans-sinus (implant #15 marked by the arrow) with a double bicortical anchorage (implant anchored to the maxilla, sinus and nasal corticals as indicated by the red circles) as opposed to implant #25, which is inserted with bicortical anchorage.

The following exclusion criteria were used:

- emotional instability
- undergoing maxillary radiation therapy
- undergoing active chemotherapy
- patients who underwent bone grafting procedures at the planned implant sites
- patients with enough bone height bilaterally in the posterior maxilla that allowed the insertion of tilted implants through the standard protocol.

Surgical protocol

The surgical procedures were performed under local anaesthesia: articaine chlorhydrate (72 mg/1.8 ml) with epinephrine (0.018 mg/1.8 ml) 1:100,000 (Artinibsa 2%®, Inibsa Laboratory, Barcelona, Spain). All patients were sedated with diazepam (Valium® 10 mg, Roche, Amadora, Portugal) prior to surgery. Antibiotics (amoxicillin 875 mg + clavulanic acid 125 mg, Labesfal, Campo de Besteiros, Portugal) were given 1 hour prior to surgery and daily for 6 days thereafter. Cortisone medication (prednisone 5 mg [Meticorten®], Schering-Plough Farma, Agualva-Cacém, Portugal) was given daily in a regression mode (15 mg to 5 mg) from the day of surgery until 4 days postoperatively. Anti-inflammatory medication (ibuprofen, 600 mg, Ratiopharm, Carnaxide, Portugal) was administered for 4 days postoperatively starting on day 4. Analgesics (clonixine 300 mg, Clonix®, Janssen-Cilag Farmaceutica, Barcarena, Portugal) were given on the day of surgery and postoperatively for the first 3 days if needed. Antacid medication (omeprazole, 20 mg, Alter SA, Lisbon, Portugal) was given on the day of surgery and daily for 6 days postoperatively. The surgical protocol followed was described in length in a previous publication on maxillary rehabilitation through the All-on-4 concept[22].

All of the maxillae were resorbed, with less than 5 mm width in the bone crest and less than 10 mm of height between the canines in the pre-maxilla region. These maxillae had a particular anterior sinus wall anatomy that did not allow inserting a tilted implant through the standard protocol fully inside the bone. In one patient with sinusitis diagnosed preoperatively, the Schneider's membrane was not ruptured. In this situation, the procedure was the following: a window of approximately 8 mm of diameter was opened in the maxilla approximately 8 mm above the residual crest. The sinus membrane was lifted, leaving the walls free from any soft tissue. The space was limited by the anterior wall of the sinus, the nasal wall, the residual maxillary crest and the collapsed membrane.

In situations without sinusitis diagnosed preoperatively, Schneider's membrane was ruptured to insert the implant. No additional surgical care was taken when the intra-sinus fenestrations occurred. The insertion of the tilted trans-sinus implants was as follows: an under-preparation protocol was used

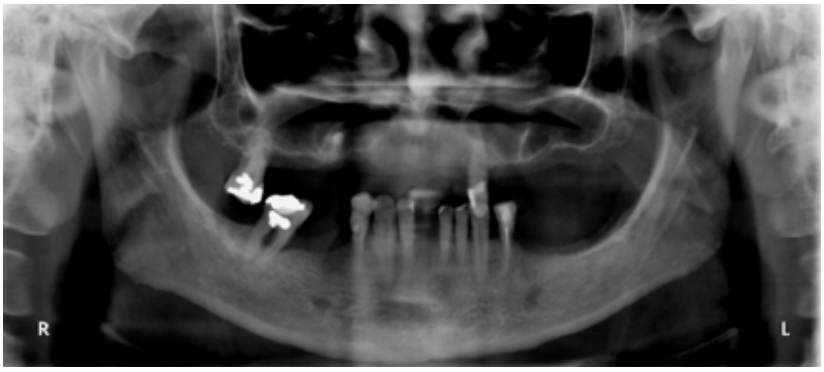

Fig 2 Preoperative orthopantomograph. Presence of compromised teeth and pneumatisation of the maxillary sinus.

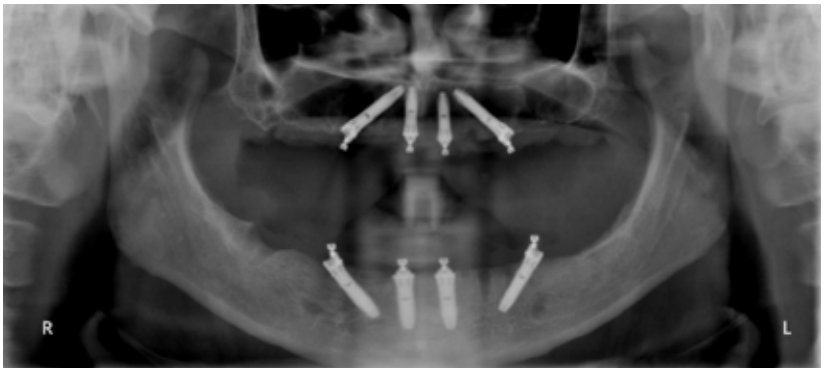

Fig 3 Postoperative orthopantomograph showing implants in positions #15 and #25 inserted trans-sinus and with bicortical anchorage (implants anchored to both maxillary and nasal corticals).

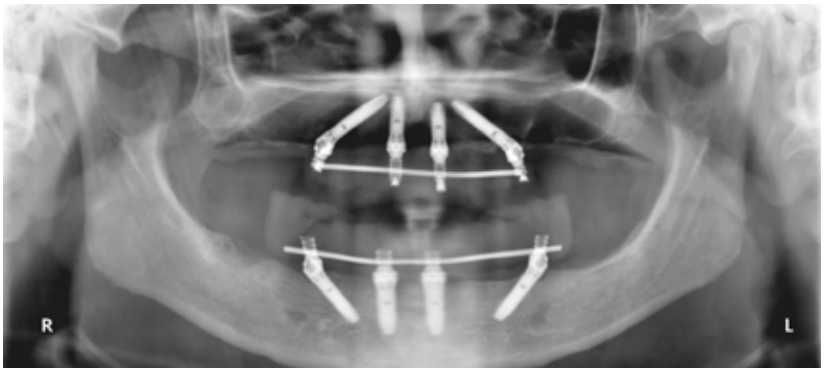

Fig 4 Orthopantomograph of the same patient at 6 months post-loading.

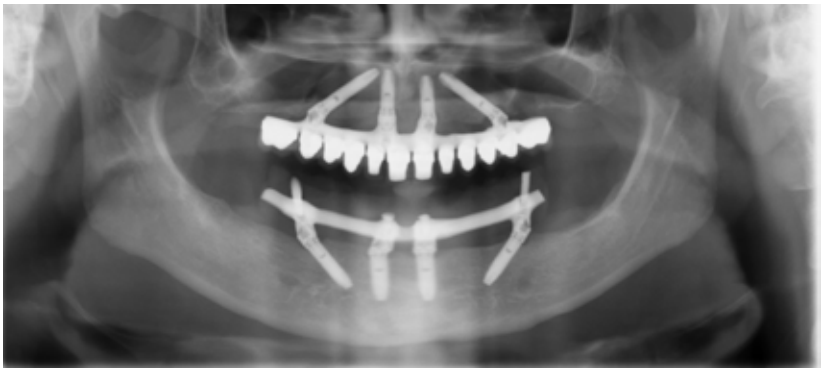

Fig 5 Orthopantomograph showing the definitive prosthesis after 1-year of follow-up.

to achieve an insertion torque of at least 32 Ncm before final seating of the implant. The 2 mm twist drill usually crossed the bone crest just anterior to the sinus wall, passed inside the sinus and entered again in the maxilla, engaging in the nasal cortical bone with an angulation up to 45 degrees. Implant length was determined according to this drilling depth. The preparation was followed by a 2.4/2.8 mm step drill and 3.2/3.6 mm (depending on bone density). In cases of high-density bone, the 3.8/4.2 mm step drills were used only in the cortical bone.

The bone available just posterior to the anterior sinus wall and inferior to the sinus floor was used to anchor the implant's head, the body of the tilted implant was inside the sinus, and the implant apex was anchored in the bone between the anterior sinus wall and the nasal cortical. The nasal cortical was used, if necessary, to achieve a double bicortical anchorage (Figure 1).

The implants were classified as trans-sinus intrasurgically and confirmed after a postoperative orthopantomograph.

All implants were 4 mm in diameter. The anterior implants were oriented vertically by a guide pin, replacing the edentulous guide (Nobel Biocare). Care was taken in the selection of the anterior implant positions not to come in conflict with the apex of the tilted posterior implants, which normally reached the canine area. The anterior implants were typically inserted in lateral or central incisor positions. With this implant arrangement, the authors aimed at allowing good implant anchorage, a large inter-implant distance, and short cantilever length with the posterior implants typically emerging at the first/second premolar position. After closing and suturing the flap with 3-0 non-resorbable sutures, the abutments were accessed by means of a punch if needed, and impression copings were placed. A representative clinical situation is illustrated in Figures 2 to 8.

Immediate prosthetic protocol

Complete arch acrylic resin prostheses (Heraeus Kulzer, Hanau, Germany)were inserted on the day of surgery (n = 70). The fabrication of the implant-supported prosthesis followed standard procedures. After suturing, an impression with putty material

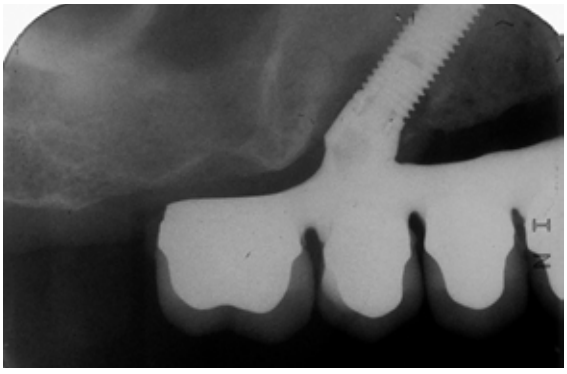

Fig 6 Periapical radiograph of implant #15 at 3 years of follow-up; 1.62 mm of bone loss was detected.

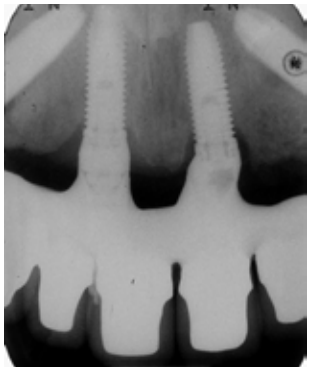

Fig 7 Periapical radiograph of implants #12 and #21 from the patient indicated in Figures 2 to 6 at 3 years of follow-up.

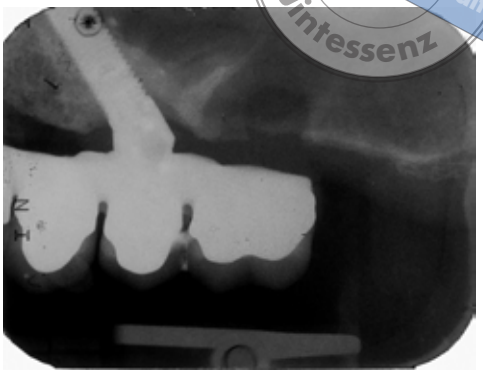

Fig 8 Periapical radiograph of implant #25 from the same patient at 3 years of follow-up.

(Elite HD+ Putty 50 ft Fast; Zhermack™, Badia Polesine, Italy) was made in a custom open tray. After tray removal, healing caps (Nobel Biocare) were placed to support the peri-implant mucosa during the fabrication of the prosthesis. A high-density acrylic resin prosthesis (PalaXpress Ultra™; Heraeus Kulzer) with titanium cylinders (Nobel Biocare) was manufactured at the dental laboratory and inserted on the same day, usually 2 to 3 hours post-surgically. Anterior occlusal contacts and canine guidance during lateral movements were preferred in the provisional prosthesis.

Final prosthetic protocol

Considering patient desires, a metal-ceramic implant-supported fixed prosthesis with a titanium framework and all-ceramic crowns (NobelProcera titanium framework, NobelProcera crowns, Nobel Rondo ceramics; Nobel Biocare), or a metal-acrylic resin implant-supported fixed prosthesis with a titanium framework (NobelProcera titanium framework) and acrylic resin prosthetic teeth (Heraeus Kulzer), were used to replace the provisional prostheses. If an adjustment of the angulated abutment was needed for better positioning of the screw access hole, the impression for the final prosthesis was taken at implant level. The abutment position was then decided at the laboratory and was adjusted in the patient's mouth. In this final prosthesis, the occlusion mimicked natural dentition. The final prosthesis was delivered typically 6 months post-surgically.

Primary outcome measures

- Implant survival was measured according to the Malo Clinic survival criteria[22]: (*i*) it fulfilled its purported function as support for reconstruction (the implants inserted were all used to support the rehabilitation), (*ii*) it was stable when individually and manually tested (at the evaluation appointments by removing the prosthesis), (*iii*) no signs of pain or persistent infection were observed (prevalent infection that could not be resolved through non-surgical or surgical interventions), (*iv*) no radiolucent areas around the implants suggestive of an implant encapsulation measured through apical radiographs or orthopantomographs.
- Prosthesis success was measured by function (not needed to be replaced by another prosthesis).
- Mechanical complications: fracture or loosening of prosthodontic components assessed clinically at each follow-up appointment and radiographically (after 1 and 3 years).
- Biological complications assessed clinically at each follow-up appointment: peri-implant pathology (presence of peri-implant pockets ≥5 mm and bone loss of ≥2 mm), soft tissue inflammation (present or absent), fistula formation (present or absent), abscess (present or absent), excessive marginal bone resorption (more than 2 mm after 1 year and more than 2.4 mm after 3 years of follow-up), prevalence of sinusitis (patient reported complaints).

Table 2 Cumulative survival rate of trans-sinus implants at patient level.

Number of patients					
Duration	**Total**	**Failed**	**Withdrawn**	**Survival rate (%)**	**Cumulative survival rate (%)**
Placement	70	3	2	95.7	95.7
1 year	65	0	3	100.0	95.7
2 years	62	0	1	100.0	95.7
3 years	61	0	0	100.0	95.7

Table 3 Cumulative survival rate of trans-sinus implants at implant level.

Number of Implants					
Duration	**Total**	**Failed**	**Withdrawn**	**Survival rate (%)**	**Cumulative survival rate (%)**
Placement	83	3	3	96.3	96.3
1 year	77	0	3	100.0	96.3
2 years	74	0	1	100.0	96.3
3 years	73	0	0	100.0	96.3

Secondary outcome measures

- Peri-implant marginal bone level changes were evaluated on periapical radiographs (Kodak, Rochester, NY) made at implant placement, and 1 and 3 years of follow-up. A conventional radiograph holder (Super-bite, Hawe-Neos, Bioggio, Switzerland) was used, and its position was manually adjusted for an estimated orthognathic position of the film, so that the position of the film was as parallel as possible to the implant. The reference point for the reading was the implant platform, that is, the horizontal interface between the implant and the abutment. The radiographs were grouped as follows: implant placement, and 1 year and 3 years post-loading. An outcome assessor examined all implant radiographs. Each periapical radiograph was scanned at 300 dpi with a scanner (HP Scanjet 4890, HP Portugal, Paço de Arcos, Portugal), and the marginal bone level was assessed with image analysis software (Image J version 1.40g for Windows, National Institutes of Health, Bethesda, Maryland, USA). The reference point for reading was the implant platform (the horizontal interface between the implant and the abutment), and marginal bone remodelling was defined as the difference in marginal bone level relative to the bone level at the time of surgery. The radiographs were accepted or rejected for evaluation based on the clarity of the implant threads; a clear thread guarantees both sharpness and an orthogonal direction of the radiographic beam towards the implant axis.
- Aesthetic complaints (aesthetic complaints of the patient or dentist) assessed clinically at each follow-up appointment for the patient and at prosthetic evaluation, yearly, for the dentist.
- Functional complaints (phonetic complaints, masticatory complaints, comfort complaints or hygienic complaints) assessed clinically at each follow-up appointment, collecting the patient's opinion.

Statistical evaluation

Descriptive statistics were used to classify the variables of interest. Survival was estimated as patient-specific (any implant failure in one patient) and implant-specific using the life table analysis.

Results

Seven patients (10% of the sample) with 28 implants, of which 8 were trans-sinus implants, dropped out of the study. In the first year of follow-up, 2 patients with 3 trans-sinus implants were lost to follow-up (1 patient moved away, 1 patient was unreachable). Between the first and second years of follow-up, 3 patients with 3 trans-sinus implants were lost to follow-up (all unreachable). Between the second and third year of follow-up, 2 patients with 2 trans-sinus implants were lost to follow-up (both moved away).

Primary outcome measures

- Implant survival: Three trans-sinus implants were lost in 3 patients after 2, 7, and 9 months of follow-up, giving a cumulative survival rate of 95.7% and 96.3% at patient and implant-level, respectively (Tables 2 and 3). One conventional tilted implant was lost in 1 patient (one of the patients that lost a trans-sinus tilted implant) after 23 months, giving a cumulative survival rate of 98.1% at patient/implant level (Table 4). One straight implant was lost in 1 patient (a second

patient that lost a trans-sinus tilted implant) after 2 months of follow-up, giving a survival rate of 98.6% and 99.3% at patient and implant level, respectively (Tables 5 and 6). All lost implants presented with clinical mobility. The lost implants were replaced on the same day (n =1 trans-sinus implant), after 5 months (n=1 trans-sinus implant; n = 1 conventional tilted implant; n = 1 straight implant) and 7 months (n = 1 trans-sinus implant), and maintained function without any complications.

- Prosthesis success: No prosthesis was lost, rendering a survival rate of 100%.
- Mechanical complications occurred in 36 patients with a predominance of abutment or prosthetic screw loosening (n = 28), followed by fracture of the prosthesis (n = 8 patients). Screw loosening occurred in 27 provisional prostheses and 1 definitive prosthesis, with 8 patients presenting an implant-supported fixed prosthesis as opposing dentition, 5 patients diagnosed as a heavy bruxers, and 7 patients with both an implant-supported fixed prosthesis as opposing dentition and bruxism. These problems were solved by adjusting the occlusion and manufacturing a night-guard. The fractures occurred in 6 provisional prostheses and 1 definitive prosthesis, with 2 patients diagnosed as heavy bruxers, 1 patient presenting an implant-supported fixed prosthesis as opposing dentition, and 2 patients with both (implant-supported fixed prosthesis as opposing dentition and bruxism). These complications were solved by mending the prosthesis (provisional) or repairing the ceramic (definitive prosthesis), adjusting the occlusion and further re-instruction about not overloading the prosthesis (just for patients with provisional prostheses), and manufacturing a night-guard for the patient with a definitive prosthesis. No further mechanical complications occurred.
- Biological complications occurred in a total of 26 patients and 30 implants. For the trans-sinus subgroup, there were 15 patients and 15 implants, with a predominance of peri-implant pathology (probing pocket depths of 5 mm of more concurrent with marginal bone resorption and the presence of bleeding on probing) (n = 11), followed by fistulae (n = 2), and excessive bone loss (n = 2). For the conventional tilted implants, there were 10 patients and 10 implants with peri-implant pathology. For the conventional straight implants, there were 4 patients and 4 implants with peri-implant pathology. There were 4 patients with implants in both subgroups (with1 tilted trans-sinus implant and 1 conventional tilted implant contralateral to the trans-sinus implant) that had biological complications. All episodes of peri-implant pathology and fistulae were resolved through non-surgical therapy and the administration of antibiotics, respectively. There were 2 patients who had sinusitis after surgery and during the follow-up. The patients reported pain and inflammation at the sinus,

Table 4 Cumulative survival rate of conventional tilted implants (contralateral to the trans-sinus tilted implants) at patient/implant level.

Number of patients/implants*					
Duration	**Total**	**Failed**	**Withdrawn**	**Survival rate (%)**	**Cumulative survival rate (%)**
Placement	57	0	2	100.0	100.0
1 year	55	1	3	98.1	98.1
2 years	51	0	1	100.0	98.1
3 years	50	0	0	100.0	98.1

*One conventional tilted implant per patient

Table 5 Cumulative survival rate of conventional axial implants at patient level.

Number of patients					
Duration	**Total**	**Failed**	**Withdrawn**	**Survival rate (%)**	**Cumulative survival rate (%)**
Placement	70	1	2	98.6	98.6
1 year	67	0	0	100.0	98.6
2 years	64	0	0	100.0	98.6
3 years	61	0	0	100.0	98.6

Table 6 Cumulative survival rate of conventional axial implants at implant level.

Number of Implants					
Duration	**Total**	**Failed**	**Withdrawn**	**Survival rate (%)**	**Cumulative survival rate (%)**
Placement	140	1	4	99.3	99.3
1 year	135	0	0	100.0	99.3
2 years	129	0	0	100.0	99.3
3 years	123	0	0	100.0	99.3

Table 7 Marginal bone resorption of trans-sinus implants at 1 and 3 years at patient level.

	Baseline		1 year		3 years	
Mean (mm)	0.40		0.96		1.14	
SD (mm)	0.37		0.62		0.74	
Number	34		59		50	
Frequencies	**N**	**%**	**N**	**%**	**N**	**%**
0 mm	10	29.4%	1	1.7%	0	0.0%
0.1 to 1.0 mm	22	64.7%	36	61.0%	24	48.0%
1.1 to 2.0 mm	2	5.9%	19	32.2%	20	40.0%
2.1 to 3.0 mm	0	0.0%	2	3.4%	5	10.0%
>3.0 mm	0	0.0%	1	1.7%	1	2.0%

Table 8 Marginal bone resorption of conventional tilted implants (contralateral to the trans-sinus tilted implants) at patient level.

	Baseline		1 year		3 years	
Mean (mm)	0.26		0.89		1.06	
SD (mm)	0.25		0.54		0.71	
Number	30		47		40	
Frequencies	**N**	**%**	**N**	**%**	**N**	**%**
0 mm	10	33.3%	1	2.1%	0	0.0%
0.1 to 1.0 mm	20	66.6%	32	68.1%	23	57.5%
1.1 to 2.0 mm	0	0.0%	12	25.5%	11	27.5%
2.1 to 3.0 mm	0	0.0%	2	4.3%	6	15.0%
>3.0 mm	0	0.0%	0	0.0%	0	0.0%

Table 9 Marginal bone resorption of straight implants at patient level.

	Baseline		1 year		3 years	
Mean (mm)	0.31		0.62		1.15	
SD (mm)	0.32		0.35		0.51	
Number	31		57		44	
Frequencies	**N**	**%**	**N**	**%**	**N**	**%**
0 mm	6	19.4%	0	2.1%	0	0.0%
0.1 to 1.0 mm	23	74.2%	50	87.7%	17	38.6%
1.1 to 2.0 mm	2	6.5%	6	10.5%	23	52.3%
2.1 to 3.0 mm	0	0.0%	1	1.8%	4	9.1%
>3.0 mm	0	0.0%	0	0.0%	0	0.0%

together with a nasal discharge. Both situations were resolved, one through the administration of anti-inflammatory drug, and the other through a surgical intervention to clean the sinus together with the administration of corticosteroid drugs. No further biological complications occurred.

Secondary outcome measures

- Peri-implant marginal bone levels: The percentage of readable radiographs was 54% (baseline), 86% (1-year) and 83% (3 years). The average (standard deviation) marginal bone levels at baseline for the trans-sinus, conventional tilted and straight implants were 0.40 mm (0.37), 0.26 mm (0.25), and 0.31 mm (0.32), respectively. The marginal bone resorption for the trans-sinus tilted implants were, on average (standard deviation), 0.96 mm (0.62 mm) and 1.14 mm (0.74 mm) after 1 and 3 years of follow-up, respectively (Table 7). The marginal bone resorption for the conventional tilted implants were, on average (standard deviation) 0.89 mm (0.54 mm) and 1.06 mm (0.71 mm) after 1 and 3 years of follow-up, respectively (Table 8). The marginal bone resorption for the straight implants were, on average (standard deviation), 0.62 mm (0.35 mm) and 1.15 mm (0.51 mm) after 1 and 3 years of follow-up, respectively (Table 9).
- Aesthetic complaints: No aesthetic complaints were registered during the follow-up of the study.
- Functional complaints: No functional complaints were registered during the follow-up of the study.

Discussion

To the authors' knowledge, this is the first study of the rehabilitation of the complete edentulous atrophic maxilla using trans-sinus implants without other reconstruction techniques used simultaneously (such as bone grafting and/or sinus lift). The currently described rehabilitation technique has proven to be viable, with a high implant survival rate of 95.7% and 96.3% on patient and implant level, respectively, and 100% success in terms of prosthetic rehabilitation.

The survival and marginal bone resorption results are comparable to other studies using the same rehabilitation procedure (All-on-4, Nobel Biocare) in non-atrophied maxillae and with similar follow-up: survival rates of 97.6% and 98% were reported for the short- (1 year) and medium-term (3 years) outcomes, respectively, and a marginal bone resorption of 0.9 mm and 1.52 mm after 1 and 3 years of fol-

low-up, respectively[22,25]. Judging by the comparative results between trans-sinus and conventional tilted implants, this modification of the conventional All-on-4 protocol for maxilla rehabilitation did not seem to affect the medium-term prognosis of the rehabilitations. Furthermore, in completely edentulous rehabilitations with atrophic maxillae using conventional tilted implants, the results compare favourably: in a study evaluating the performance of 4 or more implants for completely edentulous rehabilitation of the maxillae, Maló et al[23] reported a 92% survival rate for the All-on-4 concept in a high degree of atrophy.

The authors recommend the use of trans-sinus implants when it is not possible to rehabilitate the completely edentulous posterior maxillae through standard techniques with conventional tilted implants, and before choosing more complex techniques such as zygomatic implants or bone grafting procedures.

Based on the present results, the currently described technique achieves comparable results when compared to rehabilitations supported by implants in immediate function inserted in grafted bone[4,26], or the use of zygomatic anchored implants through the extra-maxillary technique (98.5%)[5]. Additionally, the use of trans-sinus implants relative to implants inserted in grafted maxillary sinuses avoids morbidity at donor sites when autogenous bone is used. Furthermore, in a systematic review of randomised controlled trials (RCT), higher probabilities of implant failure and complications (odds ratio of ≥5.0) were reported for longer implants inserted in augmented bone compared with short implants, which may suggest a trend for a higher probability of a successful outcome when using short implants in residual bone.

The survival rates of short implants reported in several studies[12-15,17,18,21-24,27-30] ranged between 94.6% and 96.7%, including six RCTs[12-15,17,18] with short-term, medium-term and long-term follow-ups. In a study evaluating early complete failures of fixed implant-supported prostheses in 'cluster failure patients' treated in the edentulous maxilla, Jemt and Hager[31] reported implant length as having a significant impact on increased failure risk. Nevertheless, this situation may be influenced by implant surface, as concluded in a systematic review that found no significant difference between short and conventional rough-surface implants placed in totally or partially edentulous patients[32]. However, these comparisons should be properly tested using a RCT. Compared to rehabilitations using zygomatic implants, the procedure with trans-sinus implants is not as technically demanding. The results achieved in terms of survival are comparable between the two techniques. For the same time period (3 years), the cumulative survival rate results of the rehabilitations using zygomatic implants in immediate function have been reported to be between 96.4% and 100%[6,33].

In the present study, sinusitis was observed in 2 patients, i.e. a prevalence rate of 2.9%. The prevalence rate was lower when compared to the prevalence reported in rehabilitations of the atrophic maxilla through zygomatic implants, where this complication is one of the most prevalent, and still possibly underestimated, since most studies do not mention the presence or absence of these complications[34]. Nevertheless, RCTs need to be performed in order to make appropriate comparisons. Tabrizi et al[35], in a retrospective study with 13 patients and 18 implants with radiographic evidence of implant exposure to the maxillary sinuses, reported absence of signs or symptoms of sinusitis owing to the avoidance of membrane tearing. Jung et al[36] evaluated 9 patients with 23 implants that had been inserted into the maxillary sinus without lifting the sinus membranes and found no clinical signs of sinusitis in any patient 6 to 10 months after implant insertion. The present study reached a similar result, as rupturing the sinus membrane in the absence of preoperative sinusitis did not seem to influence significantly the prevalence of sinus infections. However, this situation needs to be clarified in future studies.

One disadvantage of this technique was the higher prevalence of mechanical complications (nearly 50% of the sample). A similar result was observed using tilted implants in the completely edentulous rehabilitation of the atrophic maxilla and could be explained by the background of more demanding biomechanical conditions under which these patients are rehabilitated. The inclusion of larger cantilever extensions, especially in the presence of bruxism, can increase the risk of mechanical complications[23].

The study limitations are its retrospective design (it was not an RCT comparing this technique with

other techniques), the involvement of only one centre and the low percentage of baseline radiographs, which may represent a threat to the results of the marginal bone resorption towards an overestimation of the values at 1 and 3 years.

Future RCTs should focus on the long-term outcome of this rehabilitation technique in comparison to alternative techniques.

Conclusions

The high survival rate observed indicates that the outcome of immediately loaded trans-sinus implants in the rehabilitation of edentulous atrophic maxillae to avoid sinus lift procedures is a viable option in the short and medium term.

Acknowledgments

The authors would like to thank Mr Sandro Catarino, Miss Andreia Araújo and Dr Tiago Estevão (Malo Clinic Lisbon) for their help in data management.

References

1. Davo R, Malevez C, Rojas J. Immediate function in the atrophic maxilla using zygoma implants: a preliminary study. J Prosthet Dent 2007;97:S44-S51. Erratum in: J Prosthet Dent 2008;99:167.
2. Esposito M, Grusovin mg, Felice P, Karatzopoulos G, Worthington HV, Coulthard P. Interventions for replacing missing teeth: horizontal and vertical bone augmentation techniques for dental implant treatment. Cochrane Database Syst Rev 2009;(4):CD003607.
3. Kupeyan HK, Shaffner M, Armstrong J. Definitive CAD/CAM-guided prosthesis for immediate loading of bone-grafted maxilla: a case report. Clin Implant Dent Relat Res 2006;8:161-167.
4. Maló P, de Araújo Nobre M. A new approach for maxilla reconstruction. Eur J Oral Implantol 2009;2:101-114.
5. Maló P, de Araújo Nobre M, Lopes I. A new approach to rehabilitate the severely atrophic maxilla using extramaxillary anchored implants in immediate function: A pilot study. J Prosthet Dent 2008;100:354-366.
6. Maló P, de Araújo Nobre M, Lopes A, Francischone C, Rigolizzo M. Three-year outcome of a retrospective cohort study on the rehabilitaiton of completely edentulous atrophic maxillae with immediately loaded extra-maxillary zygomatic implants. Eur J Oral Implantol 2012;5:37-46
7. Kuabara MR, Ferreira EJ, Gulinelli JL, Panzarini SR. Use of 4 immediately loaded zygomatic fixtures for retreatment of atrophic edentulous maxilla after complications of maxillary reconstruction. J Craniofac Surg 2010;21:803-805.
8. Stiévenart M, Malevez C. Rehabilitation of totally atrophied maxilla by means of four zygomatic implants and fixed prosthesis: a 6-40-month follow-up. Int J Oral Maxillofac Surg 2010;39:358-363.
9. Ferreira EJ, Kuabara MR, Gulinelli JL. "All-on-four" concept and immediate loading for simultaneous rehabilitation of the atrophic maxilla and mandible with conventional and zygomatic implants. Br J Oral Maxillofac Surg 2010;48:218-220.
10. Duarte LR, Filho HN, Francischone CE, Peredo LG, Bråne-mark PI. The establishment of a protocol for the total rehabilitation of atrophic maxillae employing four zygomatic fixtures in an immediate loading system--a 30-month clinical and radiographic follow-up. Clin Implant Dent Relat Res 2007;9:186-196.
11. Bedrossian E, Rangert B, Stumpel L, Indresano T. Immediate function with the zygomatic implant: a graftless solution for the patient with mild to advanced atrophy of the maxilla. Int J Oral Maxillofac Implants 2006;21:937-942.
12. Cannizzaro G, Felice P, Minciarelli AF, Leone M, Viola P, Esposito M. Early implant loading in the atrophic posterior maxilla: 1-stage lateral versus crestal sinus lift and 8 mm hydroxyapatite-coated implants. A 5-year randomised controlled trial. Eur J Oral Implantol 2013;6:13-25.
13. Cannizzaro G, Felice P, Leone M, Ferri V, Viola P, Esposito M. Immediate versus early loading of 6.5 mm-long flapless-placed single implants: a 4-year after loading report of a split-mouth randomised controlled trial. Eur J Oral Implantol 2012;5:111-121.
14. Esposito M, Cannizzaro G, Soardi E, Pistilli R, Piattelli M, Corvino V, Felice P. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm-long, 4 mm-wide implants or by longer implants in augmented bone. Preliminary results from a pilot randomised controlled trial. Eur J Oral Implantol 2012;5:19-33.
15. Esposito M, Cannizarro G, Soardi E, Pellegrino G, Pistilli R, Felice P. A 3-year post-loading report of a randomised controlled trial on the rehabilitation of posterior atrophic mandibles: short implants or longer implants in vertically augmented bone? Eur J Oral Implantol 2011;4:301-311.
16. Esposito M, Grusovin mg, Felice P, Karatzopoulos G, Worthington HV, Coulthard P. The efficacy of horizontal and vertical bone augmentation procedures for dental implants – a Cochrane systematic review. Eur J Oral Implantol 2009;2:167-184.
17. Cannizzaro G, Felice P, Leone M, Viola P, Esposito M. Early loading of implants in the atrophic posterior maxilla: lateral sinus lift with autogenous bone and Bio-Oss versus crestal mini sinus lift and 8-mm hydroxyapatite-coated implants. A randomised controlled clinical trial. Eur J Oral Implantol 2009;2:25-38.
18. Felice P, Cannizzaro G, Checchi V, Marchetti C, Pellegrino G, Censi P, Esposito M. Vertical bone augmentation versus 7-mm-long implants in posterior atrophic mandibles. Results of a randomised controlled clinical trial of up to 4 months after loading. Eur J Oral Implantol 2009;2:7-20.
19. Jensen OT, Cottam J, Ringeman J, Adams M. Trans-sinus dental implants, bone morphogenetic protein 2, and immediate function for all-on-4 treatment of severe maxillary atrophy. J Oral Maxillofac Surg 2012;70:141-148.
20. Testori T, Del Fabbro M, Capelli M, Zuffetti F, Francetti L, Weinstein RL. Immediate occlusal loading and tilted implants for the rehabilitation of the atrophic edentulous maxilla: 1-year interim results of a multicenter prospective study. Clin Oral Implants Res 2008;19:227-232.
21. Crespi R, Vinci R, Capparé P, Romanos GE, Gherlone E. A clinical study of edentulous patients rehabilitated according to the "all on four" immediate function protocol. Int J Oral Maxillofac Implants 2012;27:428-434.

22. Maló P, de Araújo Nobre M, Lopes A, Francischone C, Rigolizzo M. "All-on-4" Immediate-function concept for complete edentulous maxillae: A clinical report on the medium (3 years) and long-term (5 years) outcomes. Clin Implant Dent Relat Res 2012;14:e139-e150.
23. Maló P, Nobre M, Lopes A. The rehabilitation of completely edentulous maxillae with different degrees of resorption with four or more immediately loaded implants: a 5-year retrospective study and a new classification. Eur J Oral Implantol 2011;4:227-243.
24. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzche PC, Vandenbroucke JP, STROBE Initiative. STROBE statement. Available at: http://www.strobe-statement.org/index.php?id=checklist. Accessed 8 June 2012.
25. Maló P, Rangert B, Nobre M. All-on-4 immediate-function concept with Brånemark system implants for completely edentulous maxillae: a 1-year retrospective clinical study. Clin Implant Dent Relat Res 2005;5:S88-S94.
26. Del Fabbro M, Testori T, Francetti L, Weinstein R. Systematic review of survival rates for implants placed in the grafted maxillary sinus. Int J Periodontics Restorative Dent 2004;24:565-577.
27. Renouard F, Nisand D. Short implants in the severely resorbed maxilla: a 2-year retrospective clinical study. Clin Implant Dent Relat Res 2005;7:S104-S110.
28. Maló P, de Araújo Nobre M, Rangert B. Short implants placed one-stage in maxillae and mandibles: a retrospective clinical study with 1 to 9 years of follow-up. Clin Implant Dent Relat Res 2007;9:15-21.
29. Maló P, Nobre Md, Lopes A. Short implants in posterior jaws. A prospective 1-year study. Eur J Oral Implantol 2011;4:47-53.
30. Tawill G, YounanR. Clinical evaluation of short, machined-surface implants followed for 12 to 92 months. Int J Oral Maxillofac Implants 2003;18:894-901.
31. Jemt T, Hager P. Early complete failures of fixed implant-supported prostheses in the edentulous maxilla: a 3-year analysis of 17 consecutive cluster failure patients. Clin Implant Dent Relat Res 2006;8:77-86.
32. Kotsovilis S, Fourmousis I, Karoussis IK, Bamia C. A systematic review and meta-analysis on the effect of implant length on the survival of rough-surface dental implants. J Periodontol 2009;80:1700-1718.
33. Balshi SF, Wolfinger GJ, Balshi TJ. A retrospective analysis of 110 zygomatic implants in a single-stage immediate loading protocol. Int J Oral Maxillofac Implants 2009;24:335-41.
34. Chrcanovic BR, Abreu MH. Survival and complications of zygomatic implants: a systematic review. Oral Maxillofac Surg 2013;17:81-93.
35. Tabrizi R, Amid R, Taha Ozkan B, Khorshidi H, Langner NJ. Effects of exposing dental implant to the maxillary sinus cavity. J Craniofac Surg 2012;23:767-769.
36. Jung JH, Choi BH, Jeong SM, Li J, Lee SH, Lee HJ. A retrospective study of the effects on sinus complications of exposing dental implants to the maxillary sinus cavity. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:623-635.