Clinical Investigation on Axial versus Tilted Implants for Immediate Fixed Rehabilitation of Edentulous Arches: Preliminary Results of a Single Cohort Study

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ABSTRACT

Purpose: The purpose of this clinical investigation was to evaluate full-arch fixed-dental restorations supported by immediate loaded axial and tilted implants in a single-cohort study. Survival rate of axial and tilted implants was compared.

Materials and Methods: From 2006 to 2010, 30 patients were recruited and treated with dental implants. Provisional fixed-dental prostheses were screw-retained over axial or axial and tilted implants within 24 hours after surgery. Follow-ups at 6, 12, and 24 months and annually up to 5 years were scheduled, and radiographic evaluation of peri-implant bone level changes was conducted.

Results: Thirty patients (20 females and 10 males) were followed up for an average of 44 months (range 18–67 months). Six patients received both upper and lower implant rehabilitations, resulting in 36 restorations. A total of two hundred two implants were placed (maxilla = 118; mandible = 84) and 46% of the fixtures were evaluated at the 4-year recall. Four axial implants were lost in three patients, leading to 98.02% implant (97.56% axial implants and 100% tilted implants) and 100% prosthetic cumulative survival rate, respectively. No significant difference in marginal bone loss was found between tilted and axial implants in both jaws at 1-year evaluation.

Conclusions: Midterm results confirmed that immediate loading of axial and tilted implants provides a viable treatment modality for the rehabilitation of edentulous arches.

KEY WORDS: dental implants, immediate loading, mandible, maxilla, tilted implants

INTRODUCTION

In the rehabilitation of full arches with dental implants, more frequently in long-term edentulism, reduced bone volume might be present in the posterior regions of the mouth because of the pneumatization of maxillary sinus or for the superficialization of the inferior alveolar nerve. To face these limitations, a clinician has different therapeutic options, such as long distal cantilever,[1] short implants,[2,3] sinus lift,[4] bone regeneration,[5] or implants placed in specific anatomical areas such as the pterygoid region,[6] the tuber,[7,8] or the zygoma.[9,10] Any of these procedures requires surgical and prosthetic expertise and has its own advantages, limits, risks, and complications, thus reducing patient's acceptance.

Recently, clinical[11–13] and experimental studies[14–17] showed several surgical and prosthetic advantages in

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tilting posterior implants, representing a viable alternative to grafting. Therefore, partial[18] or total immediate restorations over tilted and axial implants[19,20] reported high percentage of survival rates, in line with rehabilitations supported solely by conventionally placed fixtures.[21,22]

During the last decades, materials and techniques have improved continuously and immediate loading has been revealed a predictable and reliable procedure, especially for full-arch rehabilitations.[23,24] Earlier studies on immediate loading have included a high number of dental implants,[25,26] specifically when applied in the maxilla because of its poor bone density, but recent reports have shown good outcomes with the use of only four implants, two axial and two tilted.[27,28]

The ideal number of dental implants and their distribution supporting immediate fixed full-arch restorations is not reported in the literature and no clear up-to-date guidelines are present for immediate loading applications.

The aims of this study were to evaluate the clinical outcomes and patients' satisfaction with immediately loaded full-arch fixed prostheses supported solely by axial or by a combination of axial and tilted implants in both jaws and to compare the outcome of tilted versus axial fixtures in the same patients up to 5 years. The null hypothesis was that no difference in survival rate and marginal bone level change would exist between axial and tilted implants and no difference in prosthetic survival between rehabilitations supported only by axial implants or by a combination of axial and tilted implants.

MATERIALS AND METHODS

This prospective investigation was conducted according to the Declaration of Helsinki of 1975 for biomedical research involving human subjects, as revised in 2000, and it was approved by an ethics committee (Università di Foggia, Foggia, Italy). Initial examinations and inclusion of suitable patients started in 2003.

Inclusion and Exclusion Criteria

Patients were included if they were older than 18 years and physically and psychologically able to undergo implant surgery and restorative procedures (American Academy of Anesthesiologist class I or II).[29] All patients signed an informed consent to participate in the study.

Further inclusion criteria were the following: edentulous arch or presence of teeth with unfavorable long-term prognosis; adequate bone volume for implant placement at least 8 mm long and 3.7 mm wide; and patients who clearly preferred fixed implant-supported restoration without recurring to any bone graft procedures.

Exclusion criteria were the following: presence of active infection of inflammation in the area of future implant placement; hematologic diseases; uncontrolled diabetes; metabolic disease affecting bone or disease of the immune system; radiation therapy in the head or neck region in the previous 5 years; poor oral hygiene and motivation; and bruxism or clenching.

Presurgical Patient Evaluation

Arch size, bone volume, interarch relation, and distance were evaluated preoperatively by means of a clinical examination and analysis of panoramic radiographs, periapical radiographs, computerized tomography scans, radiograph of the skull in lateral view, and study models mounted in articulator.

Before the surgery, a resin transfer plate was realized as a duplicate of the patient's denture or based on a wax-up for partially edentulous patients, with a secure stop on the palate vault or on the retromolar triangle. Subsequently, an opening approximately at the level of the occlusal surface was made to use the plate as a surgical guide, as described by Biscaro and colleagues.[30]

Surgical Phase

Chlorhexidine digluconate 0.2% mouthwash (Curasept, Curaden Healthcare s.r.l., Milan, Italy) was prescribed to patients, starting 3 days before surgery and then daily for 7 days. All surgeries were performed under local anesthesia with articaine chlorhydrate with adrenaline 1:100.000 (Alfacaina N, Weimer Pharma, Rastat, Germany) and intravenous sedation with midazolam (Hypnovel 0.5–1 mg, Roche, Milan, Italy) and clordemetildiazepam (En 0.5–1 mg, Abbott s.r.l., Campoverde di Aprilia, Italy).

Implant number, diameter, length, and position were planned based on clinical and radiographic analysis, as well as the final prosthetic restoration, even though other factors, such as age and gender, patient opposing dentition, and face morphotype, were also considered. The final decision was taken intra-operatively, mainly based on bone quality and quantity and implant primary stability.

After local anesthesia, the remaining teeth were extracted and sockets were carefully debrided. A midcrestal incision was made dividing the available keratinized gingiva into half, always excluding the retromolar triangle or the maxillary tuberosity. A full thickness flap was elevated, trying to preserve vascularization as much as possible, thus reducing patient's discomfort. Direct visualization of the mental nerve was made and the anterior loop was estimated with an atraumatic periodontal probe gently placed into the canal. In the upper jaw, the vestibular bony wall was extensively exposed only in case of tilted implant placement to allow the clinician a direct understanding of sinus morphology during the drilling phase. Where necessary, regularization of the crest was performed with bony forceps and rotating instruments before stabilizing the resin transfer plate using the palatal vault or the retromolar area.

For the rehabilitation of the mandible, if the remaining bone height was more than 9 mm, six to eight implants were placed axially and symmetrically along the alveolar crest. In case of atrophic posterior ridges with less than 7 mm height from the mandibular canal, straight interforaminal implants or two axial and two posterior tilted implants were inserted. Similar considerations for the maxilla were treated with six to eight straight implants in the presence of full bone (9 mm or more) or with four axial and two tilted dental implants or two axial and two tilted implants in case of reduced bone height (less than 7 mm relatively to sinus floor) and related to bone availability between maxillary anterior sinus walls. Implants are considered tilted when they are placed with a mesiodistal inclination ranging between 20° and 40° relative to the occlusal plane (Figures 1–3).

Bone quality was evaluated based on Lekholm and Zarb classification,[31] and Tapered Screw-Vent and Spline implants (Zimmer Dental Inc., Carlsbad, CA, USA) were placed following manufacturer's instructions and trying to optimize primary stability.

Wherever necessary, peri-implant bone regeneration was performed using a combination of autogenous bone and bone substitute (Puros cancellous and cortical particles 0.25–1 mm, Zimmer Dental Inc. or Bio-Oss cancellous particles, Geistlich Pharma AG, Wolhusen, Switzerland) mixed in equal proportion and covered by a resorbable membrane (CopiOs or BioMed Extend, Zimmer Dental Inc.). In case of postextraction sockets, the gaps with the implants were filled with a mixture of autogenous bone and bone substitute without the use of any membrane.

Figure 1 Fifty-eight-year-old patient presented himself with chronic generalized periodontitis. Plaque and calculus was observed, as well as clinical attachment loss in the upper and lower dentition. Patient showed class 3 occlusion associated with Kennedy Class 2, edentulism in the posterior dentition, and mobility grade 2–3 of the remaining anterior teeth.

Shouldered abutments were placed over Spline implants, while Tapered Screw-Vent abutments and Spectra-Angle abutments (Zimmer Dental Inc.) were screw-retained to straight and tilted Screw-Vent implants, respectively.

Immediate Provisional Restoration

Copings for open tray impression were positioned over the abutments and isolated with a sterile piece of rubber dam. The stabilization of the surgical guide in patient's mouth was checked. Copings were connected to each other by orthodontic wire and acrylic resin (Pattern Resin, GC America, Alsip, IL, USA) (Figure 4) or composite Protemp 4 (3 M ESPE, Pioltello, Milan, Italy) and then fixed to the surgical guide with the same material.[30]

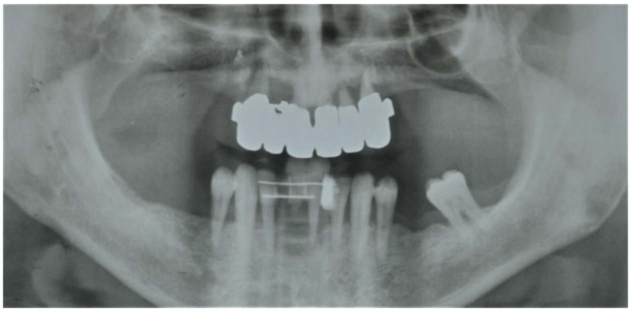

Figure 2 Panoramic x-ray evidenced severe bone loss, with horizontal resorption and some vertical defects, especially in the upper arch. Asymmetrical vertical bone conditions in the posterior maxilla in which the available bone height and width on the left side did not allow implant insertion without a preliminary sinus augmentation procedure.

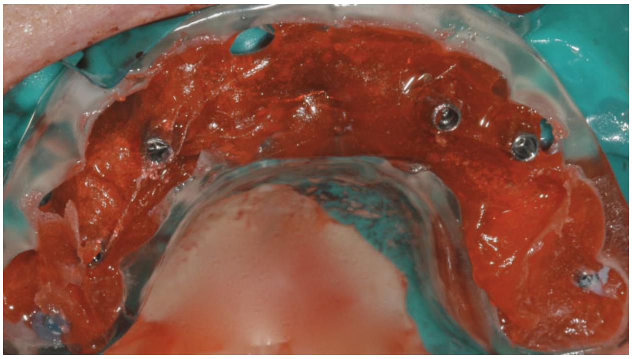

Figure 3 Splinting of the impression copings using pattern resin and orthodontic wire. All copings were bonded to the transfer plate (surgical guide) with pattern resin. [Correction made to online publication 17 June 2013: Figures 3 and 4 re-numbered.]

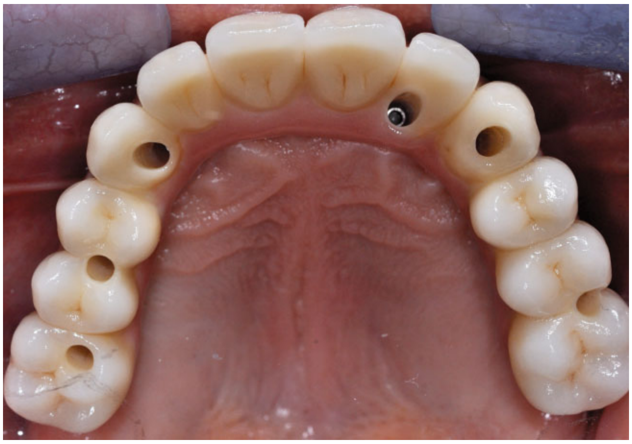

Figure 5 Occlusal view of the final maxillary fixed-dental prosthesis. Emergence of prosthetic screws was located at the occlusal surface and covered with composite.

After 5 minutes, the complex of impression copings and guide was removed, healing abutments were placed, and flaps were sutured with Gore-Tex 5/0 (WL Gore & Associates, Flagstaff, AZ, USA).

Implant analogues were screwed on the impression copings and the stone was removed from the study model in the area corresponding to implant placement. The entire complex made by surgical guide, impression copings, and analogues were positioned again over the study model. New stone was placed to secure implant analogues, converting the study model in the final master cast.[30] A screw-retained metal reinforced provisional was made and positioned in the patient's mouth the same day or within 24 hours after surgery. The immediate restoration contained no more than 12 teeth and distal cantilevers were usually avoided. Full occlusal contacts in centric occlusion were maintained for all teeth, while lateral interferences were removed.

Final Restoration Protocol

After 6 months of loading, in the absence of pain and inflammatory signs, patients received the final restoration (Figures 5–7). Titanium and zirconium-oxide frameworks were made with computer-aided designed/computer-aided manufacturing (CAD/CAM) technology, while conventional techniques were used for metal alloy prosthesis whenever financial limitations were present. Veneering porcelain, acrylic resin, or composite teeth were used as dental materials to restore the dentition according to framework and patients' desires.

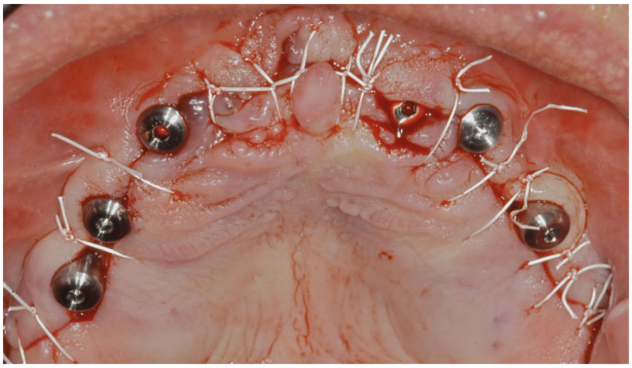

Figure 4 Tooth extraction and immediate implant placement in the maxilla. Intrasurgical application of the surgical guide allowed for implant placement in reference to future tooth positions. Six anterior implants were inserted accounting for implant position, inclination, and emergence profile. Postextraction gaps were filled with a mixture of autogenous bone and xenograft before suturing flaps with Gore-Tex 5/0.

Figure 6 Maxillary zirconium-oxide hybrid restoration screw-retained over zirconium-oxide abutments. Two implants were inserted in the location of the second premolar bilaterally. Zirconium-oxide fixed-dental prosthesis was cemented on natural teeth from first premolar to contralateral. Correction of the dental class 3 was achieved, with normal overbite and overjet.

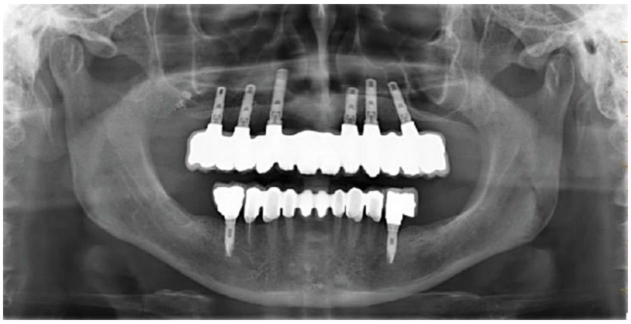

Figure 7 Final panoramic x-ray showing implant distribution and bone level on natural teeth and implants after 1 year. Implant in site #13 has been tilted to avoid sinus augmentation.

Outcome Measures

The main outcome measure for the present study was the following:

1. Prosthesis success: when the prosthesis was in function, without mobility and pain, even in face of the loss of one or more implants. Prosthesis stability was tested at each follow-up visit by means of two opposing instruments' pressure.

Secondary outcomes were the following:

1. Implant survival: when the implant was in function and stable with no evidence of peri-implant radiolucency, no suppuration or pain at the implant site or ongoing pathologic processes.[32]
2. Biological and prosthetic complications, such as peri-implant mucositis, peri-implantitis, fistulas or abscess, or any mechanical or prosthetic complications such as fracture of the implant and any prosthetic component.[33,34]
3. Marginal bone level change: periapical radiographs were performed using a long-cone paralleling technique and an individual x-ray holder at baseline, at 6 and 12 months, and yearly thereafter. Each radiograph was scanned at 600 dpi with a scanner (Epson Perfection Pro, Epson Italia, Cinisello Balsamo, Italy) and the marginal bone level was assessed with an image analysis software (UTHSCSA Image Tool version 3.00 for Windows, University of Texas Health Science Center, San Antonio, TX, USA) by an experienced blinded evaluator. The software was calibrated for every image using implant size as the known distance. The implant platform (the horizontal interface between the implant and the abutment) was used as the reference for each measurement and the linear distance between the platform and the most coronal bone-to-implant contact was measured. Mesial and distal values were averaged so as to have a single value for each implant (Figure 8). The radiographs were accepted or rejected for evaluation based on the clarity of the fixture threads. Bone loss around tilted and axial implants was compared by using paired Student's *t*-test. Analysis of variance was used to compare bone level changes over time and $p = .05$ was considered as the level of significance. A marginal bone loss of 2 mm was still considered a parameter of success.

Data Collection and Follow-Up

Patients were scheduled for weekly control visits during the first month for tissue healing assessment and prosthetic functionality.

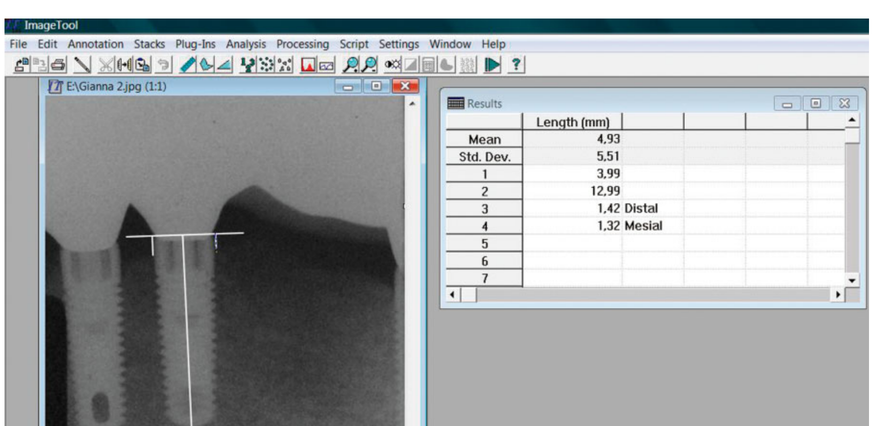

Figure 8 Measurement of marginal bone level on axial mandibular implant with dedicated software. After the calibration, the measurement is taken from the implant platform to the most coronal point of bone-to-implant contact (300 × 300 dpi).

TABLE 1 Patient distribution by gender and age. Details are provided regarding the location of the dental rehabilitation in the maxilla (Max) and mandible (Mand)

Patients, Gender	Restorations, Location	Age (Years)				
		40–50	51–60	61–70	71–80	81–90
Women ($n = 20$)	Max ($n = 13$)	1	2	5	4	1
	Mand ($n = 11$)	1	2	4	3	1
Men ($n = 10$)	Max ($n = 7$)	1	3	3	0	0
	Mand ($n = 5$)	0	3	2	0	0
Total = 30	Total = 36	3	10	14	7	2

Mand = mandible; Max = maxilla.

Periapical radiographs were taken at baseline, 6 months, 12 months, and yearly thereafter up to 5 years. A blinded biostatistician with experience in implant dentistry created a database for the analysis of all data.

During each follow-up visits, mobility of the prosthetic structure and occlusion were checked and any complication with the prosthetic components was recorded.

At the 1-year follow-up visit and annually thereafter, the prostheses were unscrewed and the stability of each implant was tested with the pressure of two opposing instruments.

RESULTS

Demographic

The study included 30 patients (10 males and 20 females; mean age 64.43 years) for a total of 36 full-arch fixed-dental rehabilitations (24 maxillae and 12 mandibles) (Table 1). Seven patients were smokers (23.3%), showing an average daily consumption of 12 cigarettes (range 5–20 cigarettes). From 2006 to 2010, a total of two hundred two implants (one hundred eighteen Tapered Screw-Vent and 84 Spline, Zimmer Dental Inc.) were placed and one hundred ninety-seven of them were immediately loaded. Five dental implants (four in the maxilla and one in the mandible) were submerged because a minimal final torque of 30 N was not reached and they were included in the final restoration. One hundred sixty-five dental implants were placed axially to the bone crest, while 37 were tilted mesiodistally between 20° and 40° according to the type of rehabilitation and anatomical conditions (Table 2). In one case, only one posterior implant was tilted less than 20° due to asymmetrical anatomic bone conditions. Yet, this choice of treatment was considered an exception. Seventy-six implants were positioned in fresh extraction sockets or in what remains of the socket after bone crest regularization; 20 of them were tilted implants and from these fixtures, eight engaged the extraction site only in the most coronal part (four Screw Vent and four Spline), while 12 passed through those sites only with their body. Only 16 implants needed buccal bone regeneration to cover the exposed threads.

Eleven maxillary arches and eight mandibles were treated with the use of 37 tilted implants in addition to 47 conventional dental implants, while 17 arches (nine maxillae and eight mandibles) were rehabilitated with a total of one hundred eighteen axial implants (66 in the upper jaw and 52 in the lower jaw) (see Table 2).

Provisional restorations always consisted of acrylic resin prosthesis reinforced with a metal framework with or without reduced distal cantilevers, while final rehabilitations changed according to patient's desires and clinician's suggestions. Twenty-nine prostheses (80.6%) were based on a CAD/CAM titanium framework; eight of them were veneered with porcelain (22.2% of the total), 13 with composite teeth (36% of the total), and eight with acrylic resin teeth (22.2% of the total). Four patients were finalized with a zirconium-oxide framework and cemented ceramic crowns (11.1%) and three with a Cr-Co alloy metal framework and acrylic teeth (8.3%). All prostheses were screw-retained, 19 on the abutments and 17 directly over the dental implants. Unilateral or bilateral distal cantilevers were present according to the extension of the opposing dentition. The opposing dentition was the following: natural teeth for seven patients, natural teeth and fixed implant protheses in three patients, natural teeth and removable prostheses in two patients, fixed prostheses on natural teeth in five patients, removable prostheses for four patients,

TABLE 2 Overview of each patient's rehabilitation including: 1) number of implants, location and distribution, 2) number of axial and tilted implants, 3) implant failures, 4) type of final restoration and material, 5) dentition or restoration of the opposing dentition

Patient No./Sex (M/F)	Arch	Position Axial Implants	Position Tilted Implants	Failure	Final Prosthesis	Final Opposing Dentition
F.G./M	Mand	31,33,35,41,43,45	/	0	Hybrid titanium with acrylic resin teeth	FDP with ceramic teeth
R.G./F	Mand	33,34,36,43,44†,46	/	0	Hybrid titanium with ceramic teeth	Hybrid titanium with ceramic teeth
R.G./F	Max	16,15,14,13,23,24,25,26†	/	0	Hybrid titanium with ceramic teeth	Hybrid titanium with ceramic teeth
C.M./F	Mand	33,34,37,43,45,46	/	0	Hybrid zirconia with ceramic teeth	Hybrid zirconia with ceramic teeth
C.M./F	Max	11,21	14,24	0	Hybrid zirconia with ceramic teeth	Hybrid zirconia with ceramic teeth
M.M./F	Max	16,14,13,12,21,23,24†,26	/	0	Hybrid titanium with acrylic resin teeth	Natural teeth and RPD
B.L./F	Mand	31,33,34,41,43,44	/	0	Hybrid titanium with acrylic resin teeth	Denture
B.M./F	Max	16,13,12,11,21,22,24,26	/	0	Hybrid titanium with acrylic resin teeth	Natural teeth
T.L./F	Mand	31,33,35,36,41,43,46,47	/	0	Hybrid titanium with ceramic teeth	Hybrid zirconia with ceramic teeth
C.L./M	Max	16,14,13,23,24,26	/	0	Hybrid titanium with ceramic teeth	FDP with resin teeth
C.T./M	Mand	32,34,35,36,42,44,45,46	/	0	Hybrid titanium with composite teeth	Hybrid titanium with composite teeth
C.T./M	Max	16,14,13,12,22,23*,24,26	/	1	Hybrid titanium with composite teeth	Hybrid titanium with composite teeth
G.A./F	Max	16,15,13,23,25,26	/	0	Hybrid titanium with ceramic teeth	Natural teeth
G.A./F	Max	16†,15,14,13,23,24,25,26		0	Hybrid titanium with ceramic teeth	Natural teeth and implants
G.G./M	Max	14,12,22,24	16,26	0	Hybrid titanium with composite teeth	FDP with ceramic teeth
S.M./M	Mand	33,34,36,43,44,46	/	0	Hybrid titanium with ceramic teeth	FDP with ceramic teeth
M.M./M	Mand	31,42	35,45	0	Hybrid titanium with acrylic resin teeth	Hybrid titanium with acrylic resin teeth
M.M./M	Max	12,22	15,25	0	Hybrid titanium with acrylic resin teeth	Hybrid titanium with acrylic resin teeth
B.B./F	Mand	32,42	35,45	0	Hybrid titanium with composite teeth	Hybrid titanium with composite teeth
B.B./F	Max	12,22	15,25	0	Hybrid titanium with composite teeth	Hybrid titanium with composite teeth
V.L./F	Max	14,12,22,24	16,26	0	Hybrid titanium with ceramic teeth	Natural teeth and implants
U.N./F	Mand	32,42	35,45	0	Hybrid titanium with acrylic resin teeth	Natural teeth
B.M./F	Max	13,11,22,23	16,26	0	Hybrid titanium with acrylic resin teeth	Natural teeth
M.F./M	Max	16,13*,11,21,23,28*	/	2	Hybrid titanium with acrylic resin teeth	Natural teeth and RPD
T.E./F	Mand	31,41	35,45	0	Hybrid titanium with acrylic resin teeth	Denture
V.I./F	Mand	32,42	35,45	0	Hybrid titanium with acrylic resin teeth	Denture
Z.C./F	Max	11,21	14,24	0	Hybrid titanium with composite teeth	Natural teeth
C.A./F	Max	16,15,13,12,22,23,25†,26	/	0	Hybrid zirconia with ceramic teeth	Natural teeth
P.A./M	Max	15,14,13,22,23	25	0	Hybrid zirconia with ceramic teeth	Zirconia crowns on natural teeth and implants
R.M./M	Mand	32,34,36,42,44,46*	/	1	Hybrid titanium with composite teeth	Natural teeth and implants
M.M./F	Mand	33,43	35,45	0	Hybrid titanium with composite teeth	Hybrid titanium with composite teeth
M.M./F	Max	13,23	15,25	0	Hybrid titanium with composite teeth	Hybrid titanium with composite teeth
P.F./M	Max	12,21	15,25	0	Hybrid titanium with composite teeth	Natural teeth
M.S./F	Mand	32,42	35,45	0	Hybrid titanium with composite teeth	FDP with ceramic teeth
L.L./F	Max	11,21	15,25	0	Hybrid titanium with composite teeth	Denture
P.L./F	Mand	32,42	35,45	0	Hybrid titanium with composite teeth	FDP with ceramic teeth
Total		165	37			

Implant positions in bold font and star (*) indicate implant failures. Implants which were submerged and therefore not included in the immediate restoration are underlined in black and show a cross (†).
F = female; FDP = Fixed Dental Prosthesis; M = male; Mand = mandible; Max = maxilla; RPD = Removable Partial Denture.

TABLE 3 Characteristics of the four failed axial implants

Patient No./Sex (M/F)	Age at Surgery (Years)	Time of Failure, Months of Function (Months)	Implant Position	Implant Diameter and Length (mm)	Insertion Torque (Ncm)	Bone Quality	Smoker (No. of Cigarettes/Day)	Reason for Failure
C.T./M	63	2	11 (axial) ✗	3.7 × 16	40	D2	Y (10)	Mobility
M.F./M	62	6	6 (axial) ✓	3.7 × 10	50	D2	Y (5)	Mobility
M.F./M	62	6	16 (axial) ✓	3.7 × 11.5	40	D3	Y (5)	Mobility
R.M./M	56	5	30 (axial) ✓	3.7 × 10	40	D3	N	Mobility

F = female; M = male; N = no; Y = yes. [Correction made to online publication 17 June 2013: title of table 3 and 4 interchanged.]

and implant-supported fixed-dental prostheses in nine patients.

Complications

No complication occurred during the surgical phase or the delivery of the immediate restoration. Breaking of esthetic veneering of the temporary prostheses occurred in two cases after 2 months of loading (5.5% of cases), while no fracture of a final prostheses or any screw loosening has been reported.

Implant Loss

Four immediate loaded implants failed in three patients before the 6-month follow-up (Table 3). One patient lost one implant in position of maxillary canine 2 months after loading, but the implant was not replaced and the patient was finalized with the remaining seven dental implants. Two dental implants in the maxilla failed in one patient and they were immediately replaced with two larger diameter dental implants (4.7 mm) in the same sites. One implant failed in position of first mandibular molar after 5 months and was replaced with an implant in position of second premolar at the same day. All these patients maintained the provisional prosthesis.

Survival Rates

The midterm patient follow-up period ranged from 18 to 67 months with a mean observation time of 44 months. All patients and implants were seen for the 1-year follow-up. For the follow-up period of 24 months, 29 arches and one hundred seventy-one implants (84%) were examined. Twenty-three arches and one hundred thirty-nine implants (69%) were summoned for the third year recall. At the fourth and fifth year recall, 14 and eight arches as well as 93 (46%) and 52 (26%) implants, respectively, were examined. After an observation time up to 5 years, a 98.02% implant ($n = 202$) and 100% prosthetic ($n = 36$) cumulative survival rate was observed. Implant survival was 98.8% in the mandible and 97.46% in the maxilla, respectively. Four axial implants belonging to rehabilitations composed solely of straight dental implants were lost, with an overall axial implant survival rate of 97.57% ($n = 165$) (95.45% for nine maxillae and 98.08% for eight mandibles) (Table 4). [Correction made to online publication 17 June 2013: 97.56% changed to 97.57% in text and in Table 4].

Bone Loss

Separate analyses were conducted for Spline (Table 5) and Tapered Screw-Vent implants (Table 6) up to 5 years of loading. The three implants replacing the failing ones were not included in the statistics. Peri-implant bone loss after 1-year follow-up could be evaluated for all patients and all 36 restorations. In the mandible, this parameter averaged 1.3 ± 0.11 mm for axial and 1.35 ± 0.12 mm for tilted implants, while in the upper jaw, it was 1.37 ± 0.14 mm for axial and 1.42 ± 0.14 for tilted implants. The difference in peri-implant bone loss was not significant between both groups ($p > .05$). Significant differences were reported at 4 and 5 years for Screw-Vent maxillary implants, but the limited number of tilted fixtures analyzed (only two samples) did not allow drawing meaningful conclusions. When bone loss around mandibular implants was compared with the corresponding maxillary implants, no significant differences were found for both axial and tilted fixtures at each time frame even though slight higher mean values were registered for the upper jaw. There were no significant differences between mesial and distal sides for axial and tilted implants in both arches as well as no relationship regarding smoking habits or baseline periodontal condition with bone loss tendency. Six of 58 axial and

TABLE 4 Cumulative survival rates for axial and tilted implants, sorted by time interval (months) of patient follow up

Time Interval (Months)	Implants at Beginning of Interval	Withdrawn Implants	Failed Implants	Interval Survival Rate (%)	Cumulative Survival Rate (%)
Axial implants					
0–6	165	0	4	97.53	97.57
6–12	164	0	0	100	97.57
12–18	164	0	0	100	97.57
18–24	156	0	0	100	97.57
24–36	141	0	0	100	97.57
36–48	111	0	0	100	97.57
48–60	85	0	0	100	97.57
>60	50	0	0	100	97.57
Tilted implants					
0–6	37	0	0	100	100
6–12	37	0	0	100	100
12–18	37	0	0	100	100
18–24	29	0	0	100	100
24–36	24	0	0	100	100
36–48	12	0	0	100	100
48–60	2	0	0	100	100
>60	2	0	0	100	100

one of two tilted maxillary implants reported more than 2 mm of bone loss (range 2.0–2.2 mm) starting from 4 years of loading; all of them were placed in postextraction sockets. Three axial mandibular fixtures reported more than 2 mm of bone loss (range 2.0–2.2 mm) starting from the 4-year follow-up. One was a posterior implant in a heavy smoker, while two were anterior implants placed in native bone.

TABLE 5 Changes in marginal bone level (mm) for Spline mandibular implants from baseline to 5-years follow-up. Axial and tilted fixtures are considered. Mean values with 95% confidence intervals

	Axial Implants (No. of Implants) Mean ± SD	Tilted Implants (No. of Implants) Mean ± SD	*p* Value
1 year	1.30 ± 0.11 (68)	1.35 ± 0.12 (16)	.13
2 years	1.45 ± 0.09 (56)	1.50 ± 0.09 (10)	.13
3 years	1.53 ± 0.09 (52)	1.58 ± 0.09 (6)	.25
4 years	1.59 ± 0.13 (40)	/	/
5 years	1.70 ± 0.18 (32)	/	/

TABLE 6 Changes in marginal bone level (mm) for Tapered Screw-Vent maxillary implants from baseline to 5 years follow-up. Axial and tilted fixtures are considered. Mean values with 95% confidence intervals

	Axial Implants (No. of Implants) Mean ± SD	Tilted Implants (No. of Implants) Mean ± SD	*p* Value
1 year	1.37 ± 0.14 (97)	1.42 ± 0.14 (21)	.14
2 years	1.48 ± 0.12 (91)	1.55 ± 0.15 (15)	.10
3 years	1.61 ± 0.13 (70)	1.70 ± 0.18 (12)	.12
4 years	1.7 ± 0.16 (58)	2 ± 0.14 (2)	.01
5 years	1.73 ± 0.14 (28)	2 ± 0.14 (2)	.02

DISCUSSION

The first aim of this study was to evaluate the outcomes for immediate implant-supported fixed-dental rehabilitations for edentulous or potentially edentulous patients. A total of 36 arches were treated with screw-retained immediate and final restorations supported by axial dental implants solely or with a combination of axial and tilted implants, getting an overall implant survival rate of 98.02%. This result is in line with similar reports on immediate rehabilitations,[23,35,36] as well as long-term clinical studies with a delayed loading protocol.[37–39]

Looking at restorations supported only by axial dental implants, Kinsel and Liss[40] reported retrospective data for 43 patients and three hundred forty-four immediately loaded Straumann implants (39 maxillary arches and 17 mandibles). Fifteen implants out of two hundred sixty-one failed in the maxilla with an implant survival rate of 94.3%, while 83 implants were placed in the mandible with one failure and 98.3% survival rate. [Correction added on 17 June 2013 after online publication: “over” changed to “out of” in the sentence.] Degidi and colleagues[21] in a 5-year retrospective study showed implant overall survival rate of 98% with three hundred eighty-eight maxillary implants placed in 43 patients, while Bergkvist and colleagues reported 97.5% cumulative survival rate at 32 months for one hundred fifty-three maxillary implants.[22]

Analyzing dental literature, survival rates for axial and tilted implant rehabilitations are comparable with the outcomes of the present investigation. Following a precise clinical protocol, Malo and colleagues reported 98.5% implant survival rate for eight hundred sixty-seven mandibular dental implants followed up for 10 years,[19] while Agliardi and colleagues showed 98.36% in the maxilla and 99.73% in the mandible up to 60 months of loading.[41] Agliardi and colleagues reported 100% success rate with the use of two axial and four tilted dental implants for the treatment of 20 maxillary arches.[42] In a systematic review, Del Fabbro and colleagues analyzed four hundred seventy immediate rehabilitations supported by a total of one thousand nine hundred ninety-two implants (one thousand twenty-six axial and nine hundred sixty-six tilted) with no differences in terms of success between maxilla and mandible and between axial and tilted implants in both arches.[43]

Implant primary stability is still considered a fundamental prerequisite for immediate loading application.[44,45] In this study, five implants with less than 30 N of final insertion torque were left submerged and later included in the final restoration. Those dental implants were either terminal abutments or located between two implants with a high level of primary stability and all of them had consistent bone augmentation on the buccal side. The authors gave priority to bone regeneration instead of support for the temporary prosthesis, taking into account that the remaining abutments could guarantee enough stability for the immediate prosthesis without compromising the osseointegration of the supporting implants. In this study, more than one-third of the implants were positioned in fresh extraction sockets and none of them failed. A careful socket debridement[46] and the underpreparation of the surgical site could guarantee high level of primary stability for the implants.

Clinical studies with different types of loading protocol evidenced excellent outcomes also with a reduced number of implants.[38,47] In 1995, Branemark and colleagues reported no significant differences between six and four axial implants[38] and recent works evidenced encouraging results with immediate function on six straight implants[22] or two axial and two tilted implants.[41,42] The present authors used between four to eight dental implants for fixed full-arch restorations based on the type of prosthetic solution, bone quality and quantity, and patient characteristics (face morphotype, dietary habits, masticatory muscles, and anatomic bone conditions). Following general guidelines, eight implants were favored in case of second molar occlusion, while six straight dental implants were used with occlusion limited to first molars. In some cases, dental implants in postextraction socket or with large peri-implant regeneration were preferred over short implants or fixtures in not ideal position to guarantee benefit for the prosthetic design. Insufficient or limited bone conditions in posterior areas of the maxilla or mandibular resulted sometimes in the placement of four/six implants, of which the two terminal ones were generally tilted in mesiodistal direction up to 40°. Tilting of implants brings surgical and prosthetic advantages as well as allowing the placement of longer implants compared with the straight insertion. Decreased long-term survival rate has been reported for implants shorter than 7 mm when compared with longer fixtures.[2,3] Shorter implants were found to be associated with increased failure rate[40,48–51] and according to the publication of Kinsel and Liss,[40] reduced implant length (less than 10 mm) was the sole significant predictor of failure during his immediate loading procedures. Also, Schnitman and colleagues[25] attributed to fixture length (7-mm implants), bone quality, and inability to get cortical engagement the failure of two of three immediately loaded implants. In the posterior area of both arches, the authors gave preference to longer implants (more than 10 mm) positioned in native bone and getting multicortical anchorage instead of shorter implants or dental implants placed with simultaneous sinus membrane elevation. The use of tilted implants up to 40° compared with axial dental implants was done according to the amount of residual bone to implant spatial distribution and prosthetic cantilever.

Observed marginal peri-implant bone loss showed no difference between axial or tilted implants after the first year of loading, which is in line with other publications investigating different implant systems.[41,52,53] Differences were also not related to jawbone, postextraction sites, or native bone and implants treated with bone grafts. According to the authors, filling the gaps between implant surface and socket with a combination of autogenous bone and allograft contributed to the reduction of the buccal bone collapse and the consequence maintenance of hard and soft tissue architecture.[54,55] Analyzing data, only a limited number of fixtures had their platform in extraction socket or in what remained of the socket after crestal bone regularization. As a consequence, the intermediate and apical part of the socket remained intact and they are usually characterized by moderate or null dimensional changes.[56] Therefore, fixtures were placed closed to the palatal or lingual side of the socket.

Provisional restorations were either delivered the same day of surgery or within 24 hours, giving the dental technician time for the creation of a metal framework to stabilize the prosthesis. Loading was distributed all along the occlusal surface, with full contact on every tooth but no interferences in lateral excursion. This concept was applied for every patient, independently of his characteristics (dietary habits, muscle activity, or face morphotype) or type of opposing dentition. Comparable clinical studies preferred limited occlusal contacts, most of the time from canine to canine, with the absence of contacts at the posterior cantilever.[41,42,57,58] Fractures of provisional restoration were of minor concern compared with other investigations,[57,58] but patients reporting history of bruxism were excluded from this study. One explanation might be related to the general presence of a metal framework and therefore extreme rigidity of the provisional restoration. [Correction added on 17 June 2013 after online publication: "provision" changed to "provisional restoration" in the sentence.] Furthermore, it is seen as an advantage of the planning phase[30] that the occlusal concept could be thoroughly evaluated before the surgical implant procedure and transferred to the provisional restorations in similar articulation.

CONCLUSION

Immediate fixed full-arch rehabilitations using a combination of tilted and axial implants or with axial implants alone proved to be a reliable technique, with advantages for both patient and clinician. The "one-model technique" simplified the prosthetic part of the treatment, providing a predictable result from diagnosis to delivery of the final prostheses. Within the limitations of this study, the promising midterm outcomes obtained seem to confirm this method as a viable treatment approach for the immediate rehabilitation of total arches.

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