Clinical Evaluation of Immediate Loading of Electroeroded Screw-Retained Titanium Fixed Prostheses Supported by Tilted Implant: A Multicenter Retrospective Study

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ABSTRACT

Statement of problem: Immediate occlusal loading of dental implants in the edentulous mandible has proven to be an effective, reliable, and predictable treatment protocol. However, there is limited long-term data available in the literature, when an electroeroded definitive cast-titanium fixed prosthesis is used for this treatment protocol.

Purpose: The aim of this study was to evaluate the clinical effectiveness of dental implants (Astra Tech Dental, Mölndal, Sweden) in the edentulous mandible immediately loaded with an electroeroded cast-titanium screw-retained fixed prosthesis.

Materials and Methods: Forty-five patients received five implants each in the interforaminal area. All the implants were inserted with torque up to 40 Ncm and the distal implants were distally tilted approximately 20 to 30 degrees to minimize the length of posterior cantilevers. Implants were loaded within 48 hours of placement with an acrylic resin-titanium screw-retained prosthesis fabricated by electroerosion.

Results: Two of the 225 inserted implants failed after 3 and 16 months of healing, respectively, with a cumulative survival rate of 99.1% and a prosthetic survival rate of 97.8%.

Conclusion: Immediate loading of tilted dental implants inserted in the edentulous mandible with a screw-retained titanium definitive prosthesis fabricated with electrical discharge machining provide reliable and predictable results.

KEY WORDS: dental implants, edentulous mandible, electroerosion, immediate loading, implant-supported prosthesis, tilted dental implants

INTRODUCTION

The rehabilitation of edentulous jaws with osseointegrated implants has been proven to be a predictable treatment over time.[1]

In implant surgery, a submerged healing of the fixtures, a waiting period of 3 to 6 months before the application of functional load, and a second surgical procedure to expose the implants were considered, for years, a prerequisite for obtaining osseointegration,[2,3] while other investigators proved a single-stage approach to be a valid treatment alternative.[4–6] Recently, immediate loading protocols have been proven as viable therapeutic alternatives, under certain circumstances.[7–9] The aforementioned protocol has been developed to reduce the number of surgical and prosthetic interventions

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and shorten the time frame between implant surgery and definitive prosthesis delivery, without sacrificing implant success rates. It has been reported that both overdentures and fixed prostheses could be installed and loaded at the time of implant surgery. Success and survival rates have been reported to be above 90%.[10,11]

Primary implant stability is considered to be one of the most important factors for successful osseointegration.[12,13] In less dense bone, undersizing osteotomies and selecting implants with differing shapes, lengths, and diameters may help to overcome such anatomical limitations and permit the attainment of high primary stability.[14,15] Over the last decade, however, the changes in implant and thread design, as well as surface configuration and a better understanding of the biological and biomechanical aspects of peri-implant osseous healing,[16,17] have improved the clinical outcome of implant treatments. Today, there is growing evidence that immediate loading can lead to survival rates comparable with those of conventionally loaded implants.[9,18]

The aim of the present study was to report, after 4 years in function, the cumulative success rate of implants immediately loaded with an electroeroded cast-titanium screw-retained implant-supported fixed prostheses on tilted and nontilted dental implants. The null hypothesis is that there would be no difference in the peri-implant probing depth and in the percentage of sites bleeding on probing in the tilted implants compared with the nontilted implants.

MATERIALS AND METHODS

Data included in this study originates from a retrospective chart review of patients treated, from January 2002 to December 2006, in two private practices (Montevarchi and Prato, Italy) and in the Department of Oral and Maxillofacial Surgery of the University of Florence. The treatment was provided by four investigators, similarly trained, who followed the same clinical protocol during placement of the dental implants and prosthetic rehabilitation.

Forty-five patients (24 males and 21 females, mean age 56.7 ± 7.94 years) were recruited for this study. Sixteen patients (35.5%) were completely edentulous and 29 (64.5%) were partially edentulous with periodontally compromised mandibular teeth with hopeless prognosis.[19] Ten patients (22%) were smokers (fewer than 10 cigarettes/day). Two (4.4%) of them presented signs of bruxism, such as wear facets. The opposing arch included natural teeth (13.3%), a complete removable prosthesis (44.4%), or a partial fixed prosthesis (42.3%), as reported in Table 1. Patients were evaluated to determine their restorative goals and psychological expectations regarding fixed or removable prosthesis. Patients were offered the choice between the well-documented conventional loading protocol using standard implant procedure or the present approach of immediate loading. Treatment alternatives were thoroughly explained and a signed consent was obtained prior to surgery. For each patient, a thorough clinical examination, including study casts, panoramic and computerized tomography imaging system were obtained to assess the viability of implant placement. Prior to implant placement, a complete removable denture was fabricated using a semiadjustable articulator. All of the patients who were treated with an electroeroded definitive cast-titanium screw-retained implant-supported fixed prosthesis, supported by five titanium dental implants (Osseospeed, Astra Tech Dental, Mölndal, Sweden) were included in this retrospective chart review. Patients who reported in their medical history one of the following conditions, were excluded from this study: uncontrolled diabetes, radiation therapy in the head and neck regions within 12 months prior to surgery, bone graft at the implant site, pregnancy, poor oral hygiene, and lack of motivation.

TABLE 1 Descriptive Statistics

Variable		N	%
Gender	Male	24	53.3
	Female	21	47.7
Mandibular arch	Edentulous	16	35.5
	Partially edentulous	21	64.5
Smokers		10	22.0
Bruxism		2	4.4
Opposing arch	Natural teeth	6	13.3
	Fixed partial denture	19	42.3
	Complete removable denture	20	44.4

The following success and survival criteria were applied in evaluating each implant: (1) no mobility of the individual unattached implants when clinically tested; (2) no evidence of peri-implant radiolucency on periapical radiographs; (3) crestal bone loss not exceeding 1.2 mm by the end of the first year of functional loading and less than 0.2 mm/year in the following

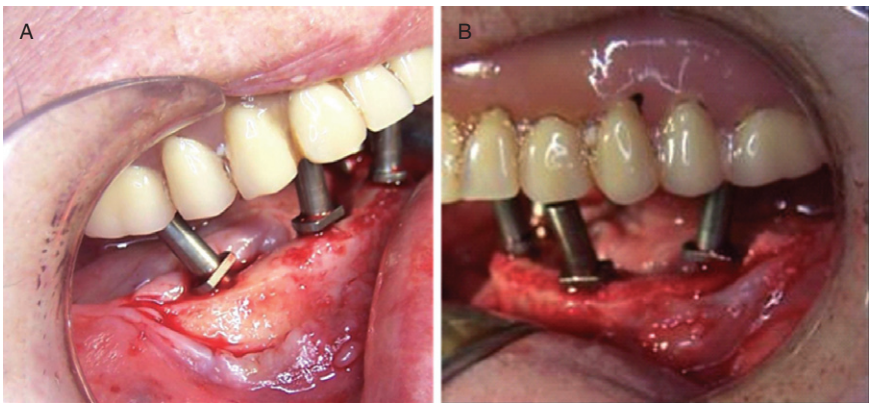

Figure 1 Guide pins inserted in the implant osteotomies, which show the implants distribution and the two distal implants tilted approximately 20 to 30 degrees. 148 × 64 mm (150 × 150 DPI).

years; and (4) absence of persistent pain, infections, neuropathies, paresthesia, or violation of the mandibular canal.[20] The prosthetic success and survival rate was evaluated according to the criteria proposed by Simonis and coauthors.[21]

Surgical Procedure

All patients were instructed to use chlorhexidine digluconate 0.2% (Curasept 0.2%, Curaden Healthcare Srl, Milan, Italy) for chemical plaque control, which started 3 days prior to surgery and continued for 10 days postoperatively. Preoperative antibiotic prophylaxis was administered with 2 g of amoxicillin (Zimox, Pfizer Italia Srl, Rome, Italy) 1 hour before surgery and 1 g every 12 hours for 6 days thereafter.

On the day of surgery, the patients were prepared for an aseptic procedure and anesthetized by local infiltration (4% articaine with 1:100,000 adrenaline; Alfacaina SP, Dentsply Italy Srl, Rome, Italy). Midcrestal horizontal and vertical medial releasing incisions were made and mucoperiosteal flaps were elevated to access the alveolar bone. Hopeless teeth, if present, were extracted. The ridge was flattened and the provisional denture was used as a surgical template to guide ideal preparation of the implant sites relative to the prosthesis design. The first implant osteotomies were performed for the distal implants, which were located anteriorly to the mental foramina and distally inclined approximately 20 to 30 degrees (Figure 1, A and B). This inclination of the distal implants allowed locating the emergence of the distal implants in the premolar/molar areas, therefore increasing the anterior-posterior spread of the implants, without compromising the integrity of the inferior alveolar nerve. The next implant was placed in the symphysis region and then, two additional implants were placed at adequate distance from the medial and distal implants (see Figure 1, A and B). The osteotomies were prepared according to manufacturer's instructions. The minimal insertion torque reputed acceptable to proceed with immediate loading was 35 Ncm. The insertion torque of all the 225 implants inserted was at least 30 Ncm. Conically shaped abutments (20° Uni-abutment, Astra Tech Dental) were screwed onto the implants (Figure 2) and the flap was sutured with an absorbable Vycril 3-0 suture (Vicryl Rapid, Ethicon, Johnson & Johnson, Roma, Italy). Distribution of implant diameters and lengths, per group, is reported in Table 2. Panoramic and periapical radiographs were obtained at the end of the surgical phase. Anti-inflammatory regimen was prescribed as needed using nonsteroidal anti-inflammatory drugs.

Prosthetic Procedures

Impression copings (20° UniAbutment Pick-up, Astra Tech Dental) were screwed onto the abutments and were

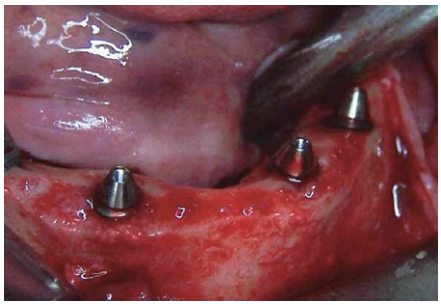

Figure 2 Conically shaped Uni-abutment screwed onto implants before flap closure. 98 × 67 mm (150 × 150 DPI).

TABLE 2 Implant Distribution per Group

Diameters (mm)	Length (mm)	Tilted	Nontilted	Total (%)
3.5	11	–	9	9 (4)
	13	27	26	53 (23.6)
4	11	–	53	53 (23.6)
	13	63	47	110 (48.8)
Total (%)		90 (40)	135 (60)	

connected with autopolymerizing acrylic resin (Pattern Resin, GC America Inc., Alsip, IL, USA). After resin polymerization, the splint thus obtained was sectioned in the area between the implants with a disk; then, the sections were once again connected with the same resin in order to compensate for the tension induced by shrinkage of the material. The provisional denture was then seated on the posterior parts of the alveolar ridges without interference with the impression copings and served as an individual impression tray. Using an impression syringe, polyether impression material (Impregum, 3 M Espe AG, Seefeld, Germany) was injected under the impression copings/acrylic splint assembly and into the inner part of the provisional denture. The patient was asked to close his jaw in the preestablished occlusal contact position and maintain this position until the impression material had polymerized. The impression copings were then unscrewed. The impression was removed from the mouth and healing abutments of appropriate height (Healing Abutment 3.5/4.0, diameter 4.5 mm, Astra Tech Dental) were screwed on the abutments to prevent flap closure during prosthesis fabrication.

A one-piece, cast-titanium, complete-arch, screw-retained framework was fabricated and then subjected to electroerosion to improve prosthesis fit. The Sae-Secotec System (SAE Dental Vertribes GMBH Lamgener, Bremerhavem, Germany) for Astra Tech Dental implants was used. The kit included implant analogue leads, copper implant electrodes, plastic cylinder for framework waxing-up, laboratory screws, and standardized insertion instruments for electrodes and screws (Figure 3).

First, implant analogues were screwed on the implant analogue leads with a prescribed torque (15 Ncm) using a torque-wrench supplied by the manufacturer (Universal Torq control, Anthogyr, Sallanches, France). The implant analogue leads and the implant analogue were connected with a copper wire and screwed to the impression copings. After this, the wires were twisted together and the impression was poured in Type IV dental stone (Fujirock E, GC Europe, Leuven, Belgium) to obtain the master cast, however, leaving the copper wire ends exposed. Then, four notches were made on the buccal surface of the cast for indexing purposes. A vinyl-polysiloxane buccal index, extending to the occlusal surfaces of the denture teeth was fabricated. Plastic cylinders (Semi-burnout Cylinder, Astra Tech Dental) were placed and retained using prosthetic screws (Lab Abutment Screw, Astra Tech Dental) and the framework was waxed. The titanium casting machine (Rematitan, Dentaurum J.P. Winkelstroeter KG, Ispringen, Germany) used electric-arc melting in an argon atmosphere with injection of the molten metal into the mold by vacuum. Grade 1 commercially pure titanium (Rematitan) was cast at a casting temperature of 1668°C, according to the manufacturer recommendations. After casting, the frameworks were evaluated for passive fit with the Sheffield test[22] (Figure 4A): A single screw was tightened at the end of the framework and the eventual creation of interfacial gaps was observed at the implant sites which were not tightened. (Figure 4B).

The electroerosion procedure was applied using a commercially available electrical discharge machine (SAE Secotec EDM 2000, SAE Dental Vertribes GMBH Lamgener, Bremerhavem, Germany). The cast was fixed horizontally in the unit and moved to the correct position under the framework holder to which the

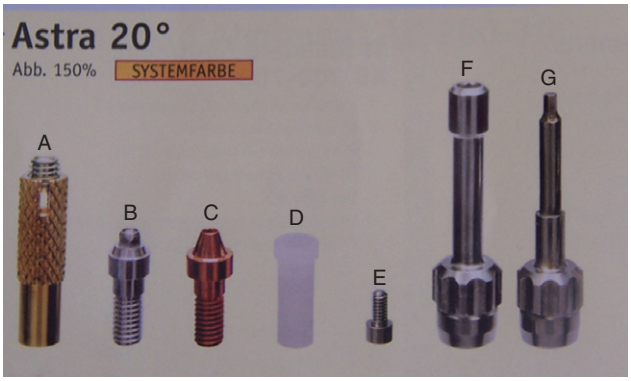

Figure 3 Sae-Secotec electroerosion components for Astra Tech implants: (A) implant analogue lead; (B) implant analogue; (C) copper electrodes; (D) plastic cylinder for framework waxing-up; (E) laboratory screws; (F–G) standardized insertion instruments for electrodes and screws. 117 × 70 mm (150 × 150 DPI).

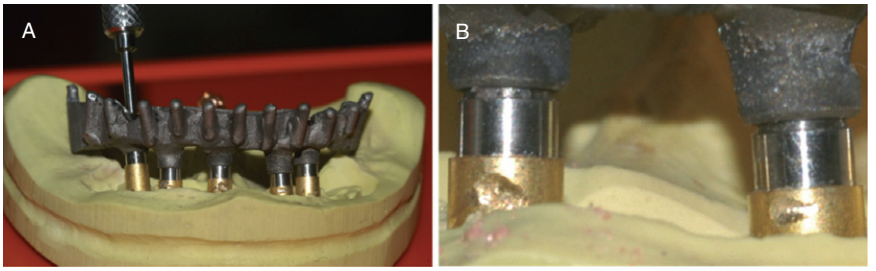

Figure 4 (A) Sheffield test of titanium framework before electroerosion; (B) at a higher magnification of the misfit of titanium framework/abutments interface, nontightened sites, before electroerosion. 174 × 51 mm (150×150 DPI).

framework was connected using acrylic resin (Pattern Resin) (Figure 5). The framework and the copper wire connected to the implant analogues placed in the cast were then connected to the electrical circuit. The framework holder lifts the framework from the cast so that the implant analogues can be replaced with the copper electrodes that are tightened at the same prescribed torque. Before initiating the electroerosion process, the entire prosthesis was immersed in a dielectric fluid, which simultaneously functioned as a coolant, insulator, and conductor (Figure 6A). The electrical discharge machine generator automatically controlled the vertical stem movements, the amperage, and the frequency of electric discharges. In this procedure, bursts of electricity, or sparks, between the copper electrode and the metal workpiece incrementally erode small amounts of the metal substrate. The up-and-down stem movements were continuous, and during the procedure, the sparks resulting from the process were visually evident. At the end of the first cycle (10 minutes), erosion was evident on the copper electrodes in the areas of premature contacts (Figure 6B); therefore, the copper electrodes were replaced with new ones and the erosion process was continued. When copper electrodes exhibit circumferential and homogeneous erosion, this phase of the erosion process was finished. The copper electrodes were then renewed again and electroerosion was restarted for the third time at a much lower power setting, which produced extremely smooth surfaces of the casting.

Each framework required different amounts of time for the electroerosion process (30–45 minutes). After the procedure, new readings of interfacial gaps between the abutments and prostheses were obtained following the previously described methodology.[22] The Sheffield test confirmed a definitive improvement of framework fit (Figure 7).

The master cast was then cross-mounted with the maxillary cast by replacing the provisional denture on the cast for occlusal reference on the same articulator previously used for the fabrication of the provisional denture. Resin teeth (Vivodent PE, Ivoclar Vivadent, Schaan, Liechtenstein) were then arranged on the metallic framework with wax. The teeth set-up was then tried in the patient's mouth after removal of the healing abutments (Figure 8A). After verifying passive fit, occlusal contacts, vertical dimension of occlusion, aesthetics,

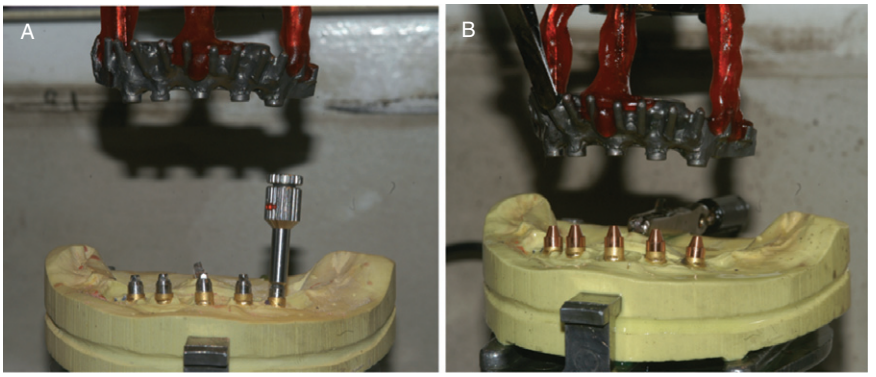

Figure 5 (A) The holder of the spark erosion unit leaves the framework from the model, and (B) the implant analogue is replaced with the copper electrodes. 175 × 72 mm (150 × 150 DPI).

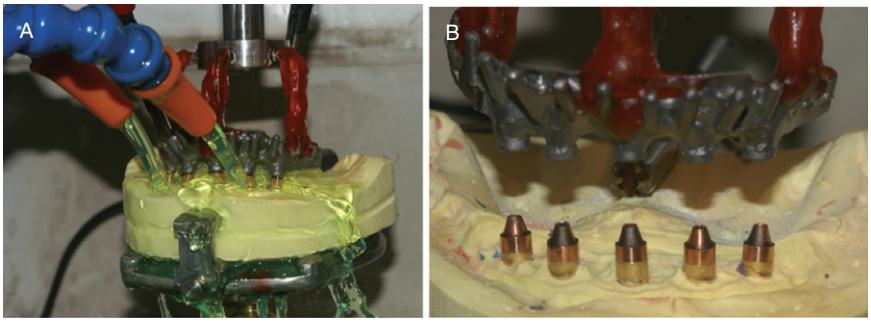

Figure 6 (A) The prosthesis immersed in a dielectric fluid to initiate the electroerosion process; (B) spark erosion on copper electrodes after the first cycle of electrical discharge machining. 175 × 60 mm (150 × 150 DPI).

and lip support, patient's approval was obtained. The definitive mandibular prosthesis was then completed and delivered within 48 hours of the implant surgery (Figure 8B); fixation screws were tightened at 20 Ncm as suggested by the manufacturer, and a panoramic radiograph was taken to confirm the passive fit of the definitive prosthesis and used as a baseline for marginal bone loss measurements (Figure 9). Oral hygiene and postoperative home care instructions were provided. After 10 days a clinical follow-up was scheduled to confirm prosthesis stability and to remove residual sutures.

Clinical and Radiological Follow-Up Protocol

After 3 months and at each following recall examination, the prosthesis was removed to evaluate individual implant mobility, presence of pain, paresthesia, peri-implant probing depth, peri-implant bleeding on probing, and/or suppuration. Between January 2002 and

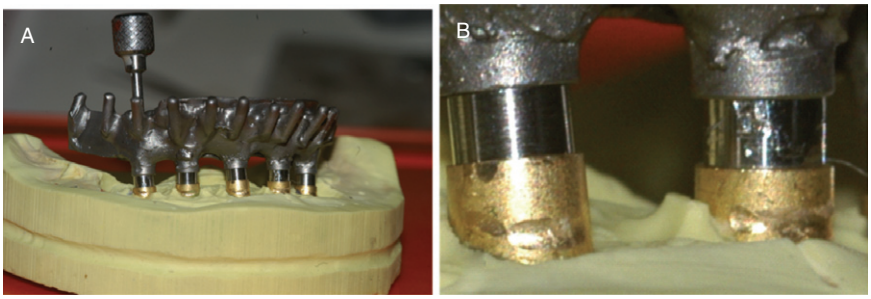

Figure 7 (A) Sheffield test of titanium framework after electroerosion; (B) at a higher magnification framework/abutments interface, nontightened sites, after electroerosion. 174 × 57 mm (150 × 150 DPI).

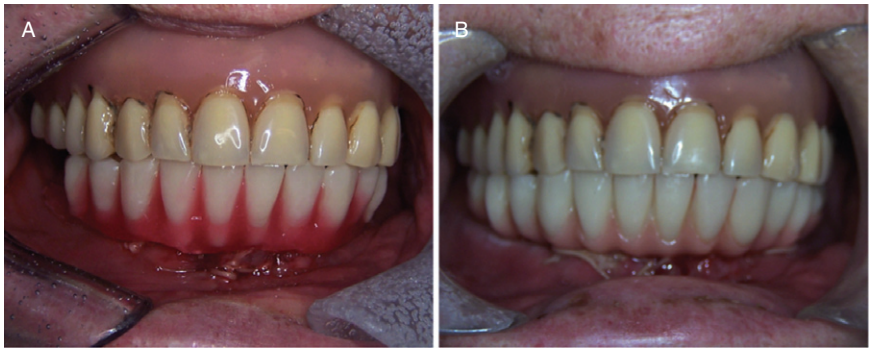

Figure 8 (A) The waxed framework with artificial teeth tried intraorally to achieve confirmation of the occlusal contacts, centric relation, vertical dimension of occlusion, aesthetics, and lip support. (B) Definitive mandibular prosthesis seated on the implants within 48 hours of the surgery. Section of a panoramic radiograph taken 48 hours of the surgery (baseline), confirming the optimal passive fit of the definitive prosthesis. 166 × 64 mm (150 × 150 DPI).

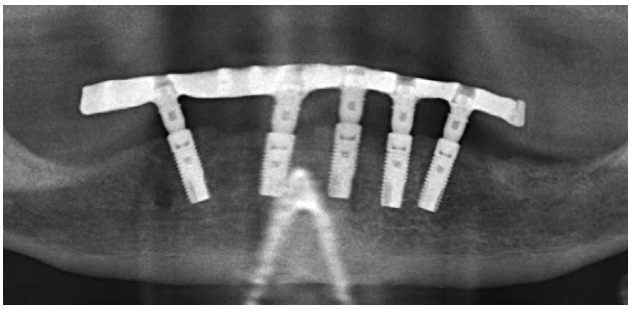

Figure 9 Section of a panoramic radiograph taken 48 hours of the surgery (baseline), confirming the optimal passive fit of the definitive prosthesis. 171 × 82 mm (150 × 150 DPI).

December 2006, the subjects were recalled, at least twice a year, for maintenance therapy consisting of scaling and oral hygiene instructions and motivation. At least once a year, clinical and radiographic (Figure 10) examinations were conducted, consisting of removal of the prostheses to evaluate individual implant mobility (dichotomous), presence of pain (scale from 0 to 5), paresthesia (dichotomous), peri-implant probing depth (sensitivity 1 mm) (PIPD), peri-implant bleeding on probing (dichotomus) (BOP) and/or suppuration. Incidence and nature of prosthetic complications were also recorded, including: wear of the veneering resin, fracture of the veneering resin, screw loosening, screw fracture, and framework fracture. The aforementioned variables were recorded in an electronic database (Excel; Microsoft, Redmond, WA, USA) and statistical analysis was conducted using the statistical software SAS 9.2 (SAS Institute Inc., Cary, NC, USA). The paired *t*-test ($\alpha = 0.05$) was used to compare the difference in BOP and PIPD between the tilted implants and the nontilted implants at 12-, 24-, 36- and 48-month follow-up.

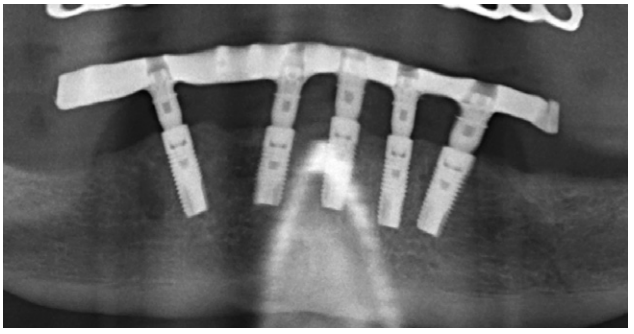

Figure 10 Section of a panoramic radiograph taken 48 months after implants loading showing no clinically relevant marginal bone loss. 158 ×83 mm (150 × 150 DPI).

RESULTS

The electroerosion procedure visibly reduced the interfacial gaps between the abutment and casting in all the 45 fabricated prosthesis, and allowed all 45 frameworks to fit on the abutments without need for further adjustments. Two of the 225 implants inserted showed radiographic sign of bone loss and mobility at the follow-up examinations. One implant (nontilted) failed after 3 months of healing in a patient who was a smoker and presented natural dentition in the opposing arch. The failed implant was removed and the prosthesis was rescrewed on the four remaining implants. The second implant (tilted) failed after 16 months; the patient was a smoker and a bruxist and presented natural dentition in the opposing arch. The latter failed implant was removed, another implant was placed, and a new prosthesis was fabricated. The two patients with failure (for a total of 10 implants, 2 failures, and 8 unaccounted for) were excluded from the remaining portion of the study. All the remaining 215 implants were accounted for during the 48-month follow-up period. No patient dropped out of the study. The life table analysis is reported in Table 3.

After 24, 36, and 48 months, there were no other implant failure, resulting in a cumulative implant survival rate of 99.1%. The survival rates for tilted and nontilted implants after 4 years of loading were 98.9% and 99.3%, respectively. There were no signs or symptoms of pain or peri-implant infection during any of the clinical examinations for the remaining patients, with the exception of the immediate postsurgical period, during which 11 patients (24.4%) presented mild edema and inflammation. After 48 months, none of the 223 surviving implants presented the crater-like peri-implant bone resorption pattern that frequently develops after the first few months of occlusal loading. During the 4-year follow-up, 11 patients (six of them with opposing natural dentition, and five with opposing partial fixed prostheses) showed extensive wear of acrylic resin teeth, while three patients showed fracture of the veneering resin and needed repair. Both types of complication could be managed by replacing the missing/broken acrylic teeth, without need for fabrication of a new prosthesis. No other complications were recorded, resulting in a prosthetic survival rate of 97.8% after 4 years and a prosthetic success rate of 66.7%.

TABLE 3 Life Table Analysis

Time Period (months)	Number of Surviving Implants	Number of Failing Implants	Unaccounted For	Survival Rate (%)	Cumulative Survival Rate (%)
Placement–12	225	1	4	99.6	99.6
12–24	220	1	4	99.5	99.1
24–36	215	0	0	100	99.1
36–48	215	0	0	100	99.1

The descriptive statistics of the peri-implant probing depth for the tilted and nontilted implants at the difference intervals is reported in Table 4. Mean values of the PIPD demonstrated a significant difference between the tilted implants and the upright implants at 24, 36 and 48 months. PIPD were significantly higher in the tilted implants compared with the nontilted implants at 24, 36 and 48 months ($p \leq .05$) as reported in Table 5. The PIPD on the distal surface of the tilted implants compared with the distal surface of nontilted implants was significantly higher at all intervals.

The proportion of sites bleeding on probing for tilted and nontilted implant is reported in Table 6. The comparison of BOP at 12, 24, 36 and 48 months for tilted and nontilted implants is reported in Table 7. The paired *t*-test showed no significant difference at 12 months between the tilted and the nontilted implants for most of the comparisons, while at 24 months the difference in proportion of sites BOP for tilted and nontilted implants was statistically significant ($p < .01$) in most of the cases. At 36 and 48 months the difference in proportion of sites BOP for tilted and nontilted implants were statistically significant in all of the cases ($p < .01$), as reported in Table 7.

DISCUSSION

Two null hypotheses were investigated in this study: (1) There would be no difference in the bleeding on probing around tilted and nontilted implants; and (2) there would be no difference in the peri-implant probing depth around tilted and nontilted implants. Both null hypotheses were rejected at 4 years.

For this study, the charts of all patients, who received an electroeroded prosthesis supported by two tilted and three nontilted implants, were reviewed. Intuitively, the two distal-tilted implants will present a transmucosal path of different height, longer on the distal and shorter on the mesial side. This might favor plaque

TABLE 4 Descriptive Statistics of Peri-Implant Probing Depth (PIPD) in Tilted and Nontilted Implants. All Measurements Are in Millimeters

	12 Months		24 Months		36 Months		48 Months	
	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)
Tilted	1.00–2.33	1.34 (0.29)	1.00–2.42	1.51 (0.41)	1.08–2.42	1.60 (0.27)	1.08–2.50	1.56 (0.28)
Nontilted	1.00–1.83	1.28 (0.21)	0.94–1.89	1.31 (0.22)	1.06–1.89	1.46 (0.21)	1.17–1.89	1.45 (0.18)
Mesial tilted	0.75–2.25	1.28 (0.35)	0.75–2.50	1.53 (0.62)	1.00–2.25	1.64 (0.27)	1.00–2.50	1.53 (0.33)
Distal tilted	1.00–2.50	1.32 (0.37)	1.00–2.75	1.53 (0.48)	0.75–2.75	1.52 (0.44)	1.00–2.50	1.56 (0.41)
Mesial nontilted	1.00–2.00	1.53 (0.22)	1.00–2.00	1.57 (0.22)	1.00–2.00	1.60 (0.22)	1.17–2.00	1.61 (0.22)
Distal nontilted	0.83–1.83	1.16 (0.28)	0.83–1.83	1.14 (0.27)	0.83–2.17	1.37 (0.28)	0.83–1.83	1.34 (0.23)

Measurements were recorded (in millimeters) at six sites per implant: disto-buccal, midbuccal, mesio-buccal, mesio-lingual, midlingual and disto-lingual. "Tilted" reports the range and mean of the implants in the tilted group. For each implant, one value was assigned, consisting in the mean of the six measured sites. "Nontilted" reports the range and mean of the implants in the nontilted group. For each implant, one value was assigned, consisting in the mean of the six measured sites. "Mesial tilted" reports the range and mean of the implants in the tilted group. For each implant, one value was assigned, consisting in the mean of the two mesial sites (mesio-buccal and mesio-lingual). "Distal tilted" reports the range and mean of the implants in the tilted group. For each implant, one value was assigned, consisting in the mean of the two distal sites (disto-buccal and disto-lingual). "Mesial nontilted" reports the range and mean of the implants in the nontilted group. For each implant, one value was assigned, consisting in the mean of the two mesial sites (mesio-buccal and mesio-lingual). "Distal nontilted" reports the range and mean of the implants in the nontilted group. For each implant, one value was assigned, consisting in the mean of the two distal sites (disto-buccal and disto-lingual). SD = standard deviation.

TABLE 5 ***p*-Values of Comparison of Peri-Implant Probing Depth (PIPD) in Tilted and Nontilted Implants (Paired *t*-Test, $\alpha = 0.05$)**

	12 Months	24 Months	36 Months	48 Months
Tilted versus nontilted	0.10	<0.001	<0.001	<0.01
Mesial tilted versus distal tilted	0.54	1	0.08	0.63
Mesial tilted versus mesial nontilted	<0.001	0.74	0.33	0.23
Distal tilted versus mesial nontilted	<0.01	<0.001	<0.05	<0.01

accumulation and, eventually, the establishment of peri-implant diseases such as peri-implant mucositis and peri-implantitis. Moreover, the long-term success of tilted implants finds only limited support in the literature.[23,24]

The fabrication of the framework of these implant-supported fixed prostheses benefited from the technique of electroerosion. However, it was not among the objectives of this investigation to assess the accuracy of the fit of the metal frameworks fabricated using this technique, which still lacks a strong scientific support. The authors are not aware of any technique for impression and framework fabrication that can ensure an absolute passive fit, which realistically might not even be achievable with current prosthodontic techniques.[22]

The prosthetic survival rate after 4 years of loading was 97.8% with 1 of the 45 prostheses requiring a remake. This was because of the loss of a distal implant and its consequent replacement, which did not allow reuse or readaptation of the original prosthesis. Although the prosthetic survival rate is encouraging and is in line with the results of other authors adopting a similar prosthesis design,[23,24] the overall prosthetic success rate was only 66.7%. Eleven patients, during the recall examination, showed extensive wear of the acrylic teeth used to veneer the metal framework. Three additional patients showed fracture of the veneering resin. These complications could be managed with minor laboratory repair procedures and did not require the fabrication of a new metal framework. The high incidence of complications in this study is in line with the finding of other authors[21,25] who found that the fracture of the veneering acrylic to be one of the most common complications with screw-retained implant-supported

TABLE 6 Proportion of Sites Bleeding on Probing (BOP) in Tilted and Nontilted Implants

	12 Months	24 Months	36 Months	48 Months
Tilted implant 1	0.295	0.349	0.372	0.372
Tilted implant 2	0.341	0.279	0.326	0.326
Upright implant 1	0.250	0.116	0.023	0
Upright implant 2	0.091	0.047	0.023	0.023
Upright implant 3	0.227	0.163	0.116	0.047

TABLE 7 ***p*-Values of Comparison of Bleeding on Probing (BOP) in Tilted and Nontilted Implants (Paired *t*-Test, $\alpha = 0.05$)**

	12 Months	24 Months	36 Months	48 Months
T1 versus U1	0.65	<0.01	<0.001	<0.001
T1 versus U2	<0.01	<0.001	<0.001	<0.001
T1 versus U3	0.36	<0.01	<0.01	<0.001
T2 versus U1	0.39	0.06	<0.001	<0.001
T2 versus U2	<0.01	<0.01	<0.001	<0.001
T2 versus U3	0.08	0.09	<0.01	<0.001

T = tilted; U = upright.

fixed prostheses. It is thus important to consider the incidence of this kind of complication during the development of a treatment plan. It is even more important to discuss this aspect of the implant-supported prosthetic rehabilitation with the patient, in order to avoid unexpected events that could originate disappointment for both the clinician and the patient.

From the study data, it was evident that a difference in peri-implant health around tilted and nontilted implants exists. The difference in BOP and PIPD developed only after the first year of function. This late onset of signs of peri-implant mucosal inflammation could be due to the time necessary for a complex and organized pathogenic microflora to establish in the peri-implant pockets.[26]

The presence of BOP in the peri-implant tissue has been associated with histologic presence of inflammation, while there is an absence of BOP in the healthy site.[27] Moreover, BOP has been found to have a high positive predictive value for further increase in clinical probing depth;[28] therefore, the increase BOP and PIPD around tilted implant could put them at higher risk for onset of peri-implantitis over the long term. However, the statistical significant difference of PIPD between tilted and nontilted implant, as very limited (the largest difference, at 48 months, was 0.61 mm between tilted and nontilted implants), might not have a clinical impact. A similar observation could be done for BOP, which was reported to be below 40% for the entire length of the study. Moreover, the relevance of clinical parameters such as bleeding on probing and peri-implant probing depth has not been clearly established. In fact it has been reported to be a common finding around certain type of dental implants,[29] while other authors have found it to be associated with inflammation and increase in pocket depth.[27,28]

The influence of tilted implant on stress distribution has been studied in vitro, but unfortunately clinical reports are limited.[23,24] The results of this study are in agreement with the findings of other authors,[23,24] and confirm the clinical validity of using tilted implant to support fixed prostheses.

For the length of this study, no significant difference in implant survival was present between tilted and nontilted implants, being 98.9% and 99.3% respectively. Therefore, within the limitations of this retrospective study, it can be concluded that immediate loading of definitive full-arch mandibular screw-retained fixed prosthesis supported by two tilted and three upright rigidly connected implants inserted in the interforaminal area is an effective and predictable procedure.

CONCLUSION

Within limitations of the study, it was concluded that:

- The bleeding on probing recorded around tilted implant is significantly higher than around nontilted implants.
- The mean peri-implant probing depth around tilted implant is significantly higher than around nontilted implants.
- The survival rate of tilted and nontilted implants supporting electroeroded screw-retained fixed prostheses is 98.9% and 99.3%, respectively, after 4 years. The cumulative survival rate is 99.5% after 4 years.
- The prosthetic success and survival rate of electroeroded screw-retained implant-supported fixed prostheses are 66.7% and 97.8%, respectively, after 4 years.

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