Immediate Loading of the Edentulous Maxilla with a Definitive Restoration Supported by an Intraorally Welded Titanium Bar and Tilted Implants

Marco Degidi, MD, DDS[1]/Diego Nardi, DDS[1]/Adriano Piattelli, MD, DDS[2]

Purpose: The aim of this prospective study was to evaluate the concept of intraoral welding as a suitable technique for the fabrication of a restoration for the edentulous atrophic maxilla on the day of placement of axial and tilted implants. **Materials and Methods:** Thirty patients received three axial and four tilted implants in the edentulous maxilla. Immediately after implant placement, definitive abutments were connected to the implants and then a titanium bar was welded to them using an intraoral welding unit. This framework was used as a support for the definitive restoration, which was attached on the day of implant placement. Mean marginal bone loss and radiographically detectable alteration of the welded framework were assessed using periapical radiographs immediately after surgery and at 6, 12, 24, and 36 months after placement. **Results:** Sixteen men and 14 women with an average age of 58.1 years (SD 13.6) were consecutively treated with 210 immediately loaded implants. No fractures or radiographically detectable alterations of the welded frameworks were evident. A 100% prosthetic success rate was seen at 36 months. Three (1.4%) implants had serious biologic complications, resulting in success rates of 97.8% for axial implants and 99.2% for tilted implants. The accumulated mean marginal bone loss was 0.92 mm (SD 0.75; n = 90) for axial implants and 1.03 mm (SD 0.69; n = 120) for tilted implants. The average pocket probing depths were 1.87 mm (SD 0.98; n = 90) for the axial implants and 1.95 mm (SD 0.81; n = 120) for the tilted implants. **Conclusions:** It is possible on the day of implant placement surgery to successfully rehabilitate the edentulous atrophic maxilla with a fixed, definitive restoration supported by an intraorally welded titanium framework attached to axial and tilted implants. Int J Oral Maxillofac Implants 2010;25:1175–1182

Key words: immediate loading, intraoral welding, tilted implants

Since the earliest studies of osseointegration, the rehabilitation of an edentulous maxilla with a complete-arch, implant-supported prosthesis has been considered one of the greatest clinical challenges.[1,2] The limited amount and quality of bone available at the site of implant placement,[3,4] high magnitude of muscle force in the posterior arch,[5] and poor accessibility of the area[6] were seen as major contraindications for such treatment, leading to the proposal of alternative treatment options, such as overdentures[7] and spark-erosion prostheses.[8] However, those options possessed many disadvantages, such as undesirable bulk in the contours on the palatal aspect and instability after years of use.

To provide patients with stable fixed restorations with smaller cantilevers, some authors have proposed engaging the molar/tuberosity area with implants and the technique of implant tilting. In 1992, Bahat[9] reported the placement of 72 Brånemark implants in the third molar/tuberosity area and achieved a success rate of 93% at an average follow-up after loading of 21.4 months. Thanks to these results, the author suggested that implants could be placed in the third molar/tuberosity area with a predictability close to or higher than that seen elsewhere in the maxilla. In 1996, Venturelli[10] investigated the survival of implants placed in the posterior maxilla and concluded that the use of implants in the tuberosity to support a fixed partial denture was a reliable and predictable alternative to distal cantilever prostheses or sinus elevation procedures. In 1999, Balshi et al[11] proposed the engagement of the compact bone of the pterygomaxillary plate, reporting a cumulative survival rate of 88.2% for pterygomaxillary site implant placement in edentulous maxillary arches. In the same year, Mattsson et al[12] proposed angulation of

[1]Private Practice, Bologna, Italy.
[2]Professor, Dental School, University of Chieti-Pescara, Chieti, Italy.

Correspondence to: Prof Adriano Piattelli, Via F. Sciucchi 63, 66100 Chieti, Italy. Fax: +011-39-0871-3554076. Email: apiattelli@unich.it

the implants and permitted two to five uncovered implant threads on the palatal aspect, so that implants of optimal length could be placed in the severely resorbed edentulous maxilla without any alveolar reconstruction. Other authors reported the feasibility of the tilting technique and observed improved prosthetic support and anchorage thanks to the placement of longer implants in dense bone.[13,14] This led to a simpler, more predictable, less expensive, and less time-consuming treatment compared to maxillary sinus bone grafting.[15]

In recent years, the immediate loading of tilted implants with a provisional restoration has been proposed for the treatment of the atrophic maxilla.[16–20] Different authors have reported reduced surgical invasion, shorter treatment time, and reduced costs[16]; high success rates and good esthetic outcomes with favorable maintenance of the marginal bone levels[17]; and no differences in clinical outcomes between tilted and axial implants.[18,19]

The aim of this prospective study was to evaluate the concept of intraoral welding as a suitable technique for the manufacture of a definitive restoration for the edentulous atrophic maxilla, done on the same day as the placement of axial and tilted implants.

MATERIALS AND METHODS

Any patient with a completely edentulous maxilla who was at least 18 years of age was considered eligible to be consecutively included in this prospective study. The condition of the opposing dentition was not considered to be a discriminating factor. Patients were ineligible for inclusion if they met any of the following exclusion criteria: (1) active infection in the sites intended for implant placement, (2) systemic disease that could compromise osseointegration, (3) radiation therapy treatment in the craniofacial region within the previous 12 months, (4) current smoking habit of more than 10 cigarettes per day, (5) current pregnancy or lactation, (6) signs or symptoms of bruxism, (7) quantity of bone in the posterior maxilla suitable for axial implant placement, or (8) partial maxillary edentulism.

This study was designed and conducted in full accordance with the World Medical Association Declaration of Helsinki, as revised in 2002. All patients signed a specific written informed consent document. Each of them received three axial and four tilted 3.4-mm or 3.8-mm parallel screw-shaped, grit-blasted, and acid-etched implants with an internal hexagonal connection (XiVE Plus, Dentsply Friadent). All implants were placed in healed sites by one experienced surgeon in a private dental office in Bologna, Italy. During implant placement, the insertion torque and the implant stability quotient (ISQ) were registered by a surgical unit (Frios Unit E, W&H Dentalwerk) and a digital measurement probe (Osstell). Patients were dropped from the study if any of the implants lacked good primary stability, had an insertion torque < 25 Ncm, or registered an ISQ of < 60.

Preoperative analysis of anatomical features and choice of the implant length were made using periapical and panoramic radiographs or, when available, computed tomography (Fig 1). Impressions of the maxilla and mandible were made and laboratory casts were fabricated. The color, shade, and structure of the prosthetic teeth were decided upon, and appropriate highly wear-resistant commercial denture teeth (Vita Physiodens, Vita Zahnfabrik) were chosen. Teeth were premounted on the cast on a semiadjustable articulator and joined with acrylic resin according to the anatomical shape of the maxilla. This definitive acrylic resin cross-arch restoration was then hollowed out to create a space for the future titanium framework.

All patients underwent the same antimicrobial prophylaxis (500 mg amoxicillin [Pfizer] twice daily for 5 days) starting 1 hour before surgery. Local anesthesia

(2% articaine/adrenaline 1:100,000) was administered at the time of surgery. Surgery began with a crestal incision that ran from the right to the left maxillary tuberosities. A full-thickness flap was then carefully elevated to expose the crest. In the presence of a knife-edged ridge, a mild osteoplasty of the ridge was performed under profuse irrigation with sterile saline solution. Three implant sites were chosen in the anterior maxilla; the engagement of the cortical bone of the nasal floor was considered desirable but not mandatory. Two sites were chosen to engage the posterior and the anterior walls of the sinus in each side. No surgical templates were used. All implants were placed with the 0.4-mm polished collar above the healed alveolar crest. Implants with lengths from 13.0 to 18.0 mm were used. No bone grafting material was employed. Tilted implants were placed with the angulation to the occlusal plane varying from 30 to 45 degrees.

The internal hexagonal connection of the implant was replaced by an abutment with an external circular and conical connection (MP, Dentsply Friadent) to compensate for the lack of parallelism between implants. These abutments were then connected to the implants by fastening screws with 20 Ncm of torque. A titanium cylinder (the so-called "welding abutment") was then connected to each abutment with a long pin screw. Two-part abutments were used (abutment and retaining screw) to ensure that the welded framework could be recovered after welding. A 2.0-mm-diameter bar (Bio-Micron, Limbiate) made of grade 2 commercially pure titanium was welded to the most distal abutment on the left using an intraoral welding unit (Aptiva NS 1100, EnneServizi). The bar was then shaped with a pair of How straight utility pliers (Unitek, 3M) so that its curve gently contacted the abutment next to the one that had just been welded.

Intraoral Welding

The modern intraoral welding protocol is a refinement of the technique reported by Mondani and Mondani[21] and Hruska.[22] The welding process can be subdivided into three stages: preparation, welding, and cooling.

Preparation Stage. The two electrodes of the welding pincers are placed on either side of the bar and the abutment, both of which must be clean and free of any surface oxidation. The copper electrodes at the extremity of the pincers are gently put into contact with the parts to be welded, and firm pressure is then applied. It is crucial to retain complete contact between the curved bar and the welding abutment during the entire process. Firm and constant pressure must be applied to ensure a perfect joint between the parts to be welded. The presence of water or saliva does not compromise the quality of the welded joint.

The surgical team and the patient must wear protective goggles during the entire process.

Welding Stage. An electrical charge from a previously unloaded capacitor is transferred to the copper electrodes of the welding pincers. Electrical current supplied to the electrodes instantly raises the temperature of the two titanium components to fusion point. Welding is performed without the use of filler metal and takes 2 to 5 ms to carry out.

Cooling Stage. Thanks to the different thermal conductivity of the titanium parts (19) and copper electrodes (386), the process is carried out without producing any discomfort to the patient or damage to the surrounding tissue, as no perceptible heat is transmitted to the peri-implant area. The copper electrodes dissipate all the heat that is generated. During this stage, the titanium crystallizes, and therefore the bar and the abutment must be kept under firm pressure.

The framework created by welding the titanium bar to the implant abutments was removed and the passivity of the whole structure was checked with the Sheffield one-screw test. The framework was then sandblasted (Modulars 3, Silfradent) and opaqued (OVS 2 Opaker, Dentsply Trubyte) to prevent reflection of metal light through the acrylic resin. The soft tissue was positioned around the abutments and sutured into place. The opaqued framework was repositioned in the oral cavity and the hollowed acrylic resin restoration was relined over the titanium framework with a small quantity of cold-cured acrylic resin. The vertical dimension was established and corrected using facial reference marks recorded prior to surgery. The restoration was then removed from the oral cavity and completely filled with heated pressure-processed acrylic resin. The restoration was trimmed, polished, and screwed into place the same day by fastening the screws with 20 Ncm of torque. The screw holes were closed with light-curing composite resin (Figs 2 to 5).

Observations

The following observations were made at five different times: T0 = after surgery and fitting of the definitive restoration; T1 = 6 months after surgery; T2 = 1 year after surgery; T3 = 2 years after surgery; and T4 = 3 years after surgery.

- Restoration success, defined as the absence of fractures in both the acrylic resin superstructure and the welding joints, even if one or more implants supporting the restoration have been removed.
- Implant survival, defined as the absence of implant mobility, swelling, or pain in the surgical site at the time of examination.

Fig 2a Edentulous maxilla before surgery.

Fig 2b Surgery; the implants are in place.

Fig 2c The abutments are connected to the implants.

Fig 2d The welding abutments are connected to the implants.

Fig 2e The intraorally welded framework.

Fig 2f The welded framework is removed.

Fig 2g The opaqued framework

Fig 2h The trimmed and polished definitive restoration.

Fig 2i The screw-retained definitive restoration.

- Implant success, defined as implant survival plus marginal bone loss of less than 1 mm after 1 year of loading and no more than 0.5 mm of loss between each follow-up appointment after the first year of function.
- Changes in marginal peri-implant bone level, defined as modification of the distance between the implant platform plane and the highest coronal point of the supporting bone, assessed using periapical radiographs taken with a customized positioning jig. Each periapical radiograph was digitized with a scanner (Epson Expression 1680 Pro, Epson Italia) and coded with a computerized random list generator (Quick Calc, GraphPad Software). Each coded image was then analyzed with measurement software (Meazure 2.0 build 158, C Thing Software) employing the Jaffin et al[23] protocol, using platform height and implant length as double cross references.
- Health of the marginal gingiva, as evidenced by mesial and distal probing depth measurements taken using a pressure of 0.15 N and frequency of bleeding on probing.
- Biologic and technical complications.

Fig 3 Screw-retained definitive restoration. *(a)* Clinical view; *(b)* post-surgical panoramic radiograph.
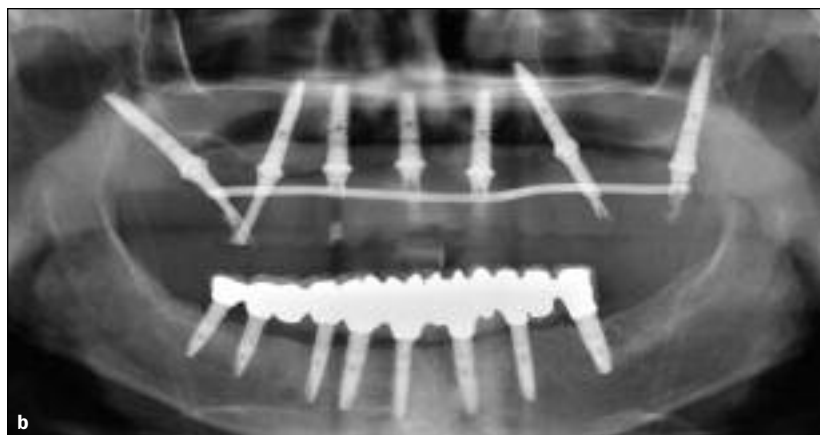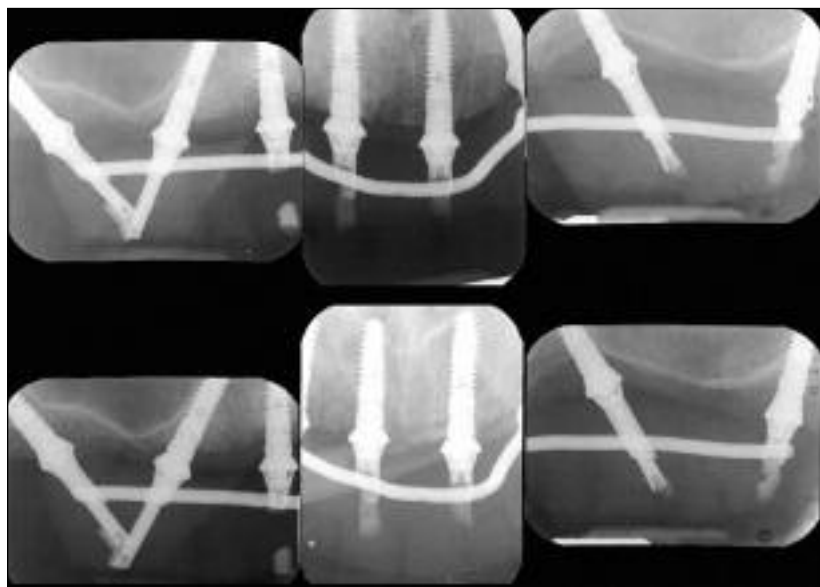

Fig 4 Lateral radiograph.

Fig 5 Periapical radiographs. *(Top row)* One-year follow-up; *(bottom row)* 3-year follow-up.

Statistical Analysis

Statistically significant mean marginal bone loss and probing depth differences ($P < .05$) between axial and tilted implants were assessed at each follow-up appointment using the *t* test.

RESULTS

A total of 90 (42.9%) axial and 120 (57.1%) tilted implants was placed in the period between July 2005 and July 2006. The mean age of the 16 men and 14

Table 1 Mean Bone Loss, Pocket Probing Depths, Bleeding on Probing, Insertion Torque, and ISQ Values

Clinical parameter/time	Tilted implants (n = 120)	Axial implants (n = 89)
Bone loss		
T0–T1	0.44 mm (SD 0.29)	0.47 mm (SD 0.31)
T1–T2	0.19 mm (SD 0.24)	0.13 mm (SD 0.11)
T2–T3	0.27 mm (SD 0.41)	0.10 mm (SD 0.09)
T3–T4	0.13 mm (SD 0.25)	0.22 mm (SD 0.06)
T0–T4	1.03 mm (SD 0.97)	0.92 mm (SD 0.89)
Probing pocket depth		
T1	1.69 mm (SD 0.52)	1.65 mm (SD 0.37)
T2	1.93 mm (SD 0.59)	1.83 mm (SD 0.49)
T3	1.91 mm (SD 0.53)	1.82 mm (SD 0.45)
T4	1.95 mm (SD 0.59)	1.87 mm (SD 0.49)
Bleeding on probing		
T1	21.6%	17.6%
T2	17.8%	15.9%
T3	15.1%	16.3%
T4	16.9%	17.3%
Insertion torque (Ncm)	35.6 (SD 5.1)	40.1 (SD 12.9)
ISQ (at T0)	67.8 (SD 4.9)	74.3 (SD 5.7)

women in the study was 58.1 years (SD 13.6; n = 30) at the time of surgery. The clinical stability of each single implant could not be verified, as the restorations were never removed unless there was a biologic problem. No statistically significant difference was observed in marginal bone resorption and probing depths between axial and tilted implants. The patients included in this study achieved a 100% prosthetic success rate at the 36-month follow-up. Three implants (1.4%) had serious biologic complications, resulting in success rates of 97.8% for the axial implants (1 problem implant and 1 failure recorded out of 90 implants) and 99.2% for the tilted implants (1 problem implant recorded out of 120 implants).

One patient, a 61-year-old male nonsmoker, reported heavy discomfort, pain, and swelling in the anterior maxilla 1 month after surgery. The restoration was removed, and subsequent examination revealed that a 3.4- × 15-mm axial implant placed in the right lateral incisor area was mobile. The implant was removed and classified as a failure. The restoration was repositioned and the patient received a cycle of 500 mg amoxicillin (Pfizer) twice daily for 5 days.

Two implants, a 3.4- × 13-mm tilted implant placed in the anterior wall area of the right sinus and a 3.8- × 15-mm axial implant placed in the left lateral incisor area, revealed progressively increasing bone resorption that led to cumulative losses of 2.81 mm and 3.07 mm, respectively, at the 3-year follow-up. In both cases, the restoration was removed and implant stability was checked. Both implants were stable, so the restorations were repositioned without any other intervention, and the implants were moved from the success group to the survival group.

Average insertion torque and ISQ values are listed in Table 1. At the 36-month follow-up, the accumulated mean marginal bone loss was 0.92 mm (SD 0.89; n = 89) for the axial implants and 1.03 mm (SD 0.87; n = 120) for the tilted implants. At the same follow-up, the average pocket probing depths were 1.87 mm (SD 0.49; n = 89) for the axial implants and 1.95 mm (SD 0.59; n = 120) for the tilted implants.

DISCUSSION

No statistically significant difference was observed in marginal bone resorption and probing depths between axial and tilted implants. Both groups showed a predictable pattern of bone response similar to that reported in previous studies.[18,19] Calandriello and Tomatis[16] reported an extremely favorable bone resorption outcome for immediately loaded tilted implants, with a mean loss of only 0.34 mm at 1 year, compared to a loss of 0.82 mm for axial implants at the same follow-up. The authors suggested that this trend was a result of the subcrestal position of the collar neck in the tilted group. This suggestion could not be verified in the present study, as all implants were placed with the 0.4-mm polished collar above the healed alveolar crest, but the finding raises some interesting questions about the feasibility of subcrestal placement of implants with a polished neck.

An analysis of the biologic complications observed in this study was unable to determine a common clinical or etiologic factor that may have caused or influenced them. The two cases of excessive bone loss

occurred in different patients and were located in different anatomical sites. The one failed implant was observed in a 61-year-old nonsmoking man with good oral hygiene practice who could not have applied excessive chewing force, as the opposing dentition was a complete removable mandibular denture. In all three patients there was a normal level of bone resorption for the remaining implants.

In a previously published paper involving immediate loading in the maxilla with the use of the intraoral welding technique,[24] Degidi et al reported a fracture of the acrylic resin superstructure 11 months after surgery. In the present study, no fractures occurred, and only moderate wear of the occlusal facets was observed in cases where the restoration opposed a ceramic prosthesis.

A major advantage of the use of the intraoral welding technique for the rehabilitation of tilted implants is granted by the immediate creation of the definitive restoration with a simple and repeatable prosthetic protocol. Although all the prosthetic components are standardized and employable for both axial and tilted implants, the restoration is custom made directly in the oral cavity of the patient, such that passivity or framework fitting problems are nonexistent. With the intraoral welding technique, the need for customized individual open tray and difficult final impression procedures is eliminated, reducing patient discomfort caused by high volumes of tissue and the presence of emetic reflex points often present in the distal areas of the maxilla.

Recently, the provisional rehabilitation of the fully edentulous maxilla with only two axial and two tilted implants with a high degree of success has been reported.[16,17] The authors of these papers reported the loss of two distal tilted implants in two patients classified as bruxers[17] and some implant losses probably resulting from crack propagation and subsequent fracture of the acrylic resin prosthesis.[16] Although a reduced number of implants leads to less invasive surgery, the presence of a distal support in the posterior sinus wall area provided support for a reduced cantilever length and increased the stability necessary to oppose the high magnitude of muscular forces in the posterior maxilla.[5] In a recent publication, Agliardi et al[25] suggested that the presence of two additional distal implants would optimize the distribution of the occlusal forces, thus reducing the stress in posterior regions of the maxilla. In the present study, no tilted implants were lost, but all patients classified as suffering from bruxism were excluded. Considering the success rate achieved by tilted implants in the present study and the objective advantages of a treatment plan with a reduced number of implants as proposed by Calandriello and Tomatis[16] and Maló et al,[17] further

studies are required to verify whether it is possible to deliver an immediate provisional restoration using a reduced number of tilted and axial implants in patients with oral parafunction.

CONCLUSIONS

It is possible on the same day of surgery to successfully rehabilitate the edentulous atrophic maxilla with a fixed definitive restoration supported by an intraorally welded titanium framework attached to axial and tilted implants.

ACKNOWLEDGMENTS

REFERENCES

1. Zarb GA, Zarb FL, Schmitt A. Osseointegrated implants for partially edentulous patients. Dent Clin North Am 1987;31:457–472.
2. DaSilva GD, Schnitman PA, Wohrle PS, Wang HN, Coch GG. Influence of site on implant survival: 6-year results [abstract]. J Dent Res 1992;71:256.
3. Lekholm U, Adell R, Brånemark P-I. Possible complications. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:233–240.
4. Sennerby L, Ericson LE, Thomsen P, Lekholm U, Astrand P. Structure of the bone-titanium interface in retrieved clinical oral implants. Clin Oral Implants Res 1992;2:103–111.
5. Mansour RM, Reynik RJ. In vivo occlusal forces and moments. I: Forces measured in terminal hinge position and associated moments. J Res Dent 1975;54:115–119.
6. Tatum H. Maxillary and sinus implant reconstruction. Dent Clin North Am 1986;30:207–229.
7. Jemt T, Chai J, Harnett J, et al. A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. Int J Oral Maxillofac Implants 1996;11:291–298.
8. Lefkove M, Beals R. Spark erosion fixed/detachable prosthesis for the completely edentulous maxilla. J Oral Implantol 1992;4:386–393.
9. Bahat O. Osseointegrated implants in the maxillary tuberosity: Report on 45 consecutive patients. Int J Oral Maxillofac Implants 1992;7:459–467.
10. Venturelli A. A modified surgical protocol for placing implants in the maxillary tuberosity: Clinical results at 36 months after loading with fixed partial dentures. Int J Oral Maxillofac Implants 1996;11:743–749.
11. Balshi TJ, Wolfinger GJ, Balshi SF. Analysis of 356 pterygomaxillary implants in edentulous arches for fixed prosthesis anchorage. Int J Oral Maxillofac Implants 1999;14:398–406.
12. Mattsson T, Kondell P-A, Gynther GW, Fredholm U, Bolin A. Implant treatment without bone grafting in severely resorbed edentulous maxillae. J Oral Maxillofac Surg 1999;57:281–287.

13. Krekmanov L, Kahn M, Rangert B, Lindstrom H. Tilting of posterior mandibular and maxillary implants for improved prosthesis support. Int J Oral Maxillofac Implants 2000;15:405–441.

14. Krekmanov L. Placement of posterior mandibular and maxillary implants in patients with severe bone deficiency: A clinical report of procedure. Int J Oral Maxillofac Implants 2000;15:722–730.

15. Aparicio C, Perales P, Rangert B. Tilted implants as an alternative to maxillary sinus grafting: A clinical, radiologic, and Periotest study. Clin Implant Dent Relat Res 2001;1:39–49.

16. Calandriello R, Tomatis M. Simplified treatment of the atrophic posterior maxilla via immediate/early function and tilted implants: A prospective 1-year clinical study. Clin Implant Dent Relat Res 2005;7:1–12.

17. Maló P, Nobre Mde A, Petersson U, Wigren S. A pilot study of complete edentulous rehabilitation with immediate function using a new implant design: Case series. Clin Implant Dent Relat Res 2006;8:223–232.

18. Capelli M, Zuffetti F, Del Fabbro M, Testori T. Immediate rehabilitation of the completely edentulous jaw with fixed prostheses supported by either upright or tilted implants: A multicenter clinical study. Int J Oral Maxillofac Implants 2007;22:639–644.

19. 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.

20. Agliardi EL, Francetti L, Romeo D, Taschieri S, Del Fabbro M. Immediate loading in the fully edentulous maxilla without bone grafting: The V-II-V technique. Minerva Stomatol 2008;57:251–263.

21. Mondani PL, Mondani PM. The Pierliugi Mondani intraoral electric solder. Principles of development and explanation of the solder using syncrystallization. Riv Odontostomatol Implantoprotesi 1982;4:28–32.

22. Hruska AR. Intraoral welding of pure titanium. Quintessence Int 1987;18:683–688.

23. Jaffin RA, Kolesar M, Kumar A, Ishikawa S, Fiorellini J. The radiographic bone loss pattern adjacent to immediately placed, immediately loaded implants. Int J Oral Maxillofac Implants 2007;22:187–194.

24. Degidi M, Nardi D, Piattelli A. Immediate loading of the edentulous maxilla with a final restoration supported by an intraoral welded titanium bar: A case series of 20 consecutive cases. J Periodontol 2008;79:2207–2213.

25. Agliardi EL, Francetti L, Romeo D, Del Fabbro M. Immediate rehabilitation of the edentulous maxilla: Preliminary results of a single-cohort prospective study. Int J Oral Maxillofac Implants 2009;24:887–895.