

# Short Implants in Maxillary and Mandibular Rehabilitations: Interim Results (6 to 42 Months) of a Prospective Study

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The aim of this single-cohort study was to evaluate clinical survival and success of partial rehabilitation supported by reduced-length implants in maxilla and mandible. Data from 53 short implants placed in 41 patients are presented. Before surgery mean residual bone height was  $6.21 \pm 1.05$  mm in the upper jaw and  $10.73 \pm 1.63$  mm in the mandible. None of the implants failed, and the cumulative survival rate was 100% at 1 year after prosthetic loading. Mean peri-implant bone loss was  $0.69 \pm 0.24$  mm for maxillary implants and  $0.73 \pm 0.23$  mm for mandibular implants, and there was no significant difference between the 2 jaws. No complications were recorded. Despite the limitations of this study concerning study design and sample size, short implants may be considered effective in supporting partial rehabilitation in both maxilla and mandible. More well-designed studies with a larger sample size and longer follow-up are needed to validate the use of short implants.

**Key Words:** short implants, fixed partial prosthesis, bone loss, atrophic jaws

## INTRODUCTION

Implant rehabilitation in the posterior regions of the maxilla and mandible can be complicated in cases of reduced bone volume due to bone resorption after teeth extraction or to particular anatomic conditions. In fact, reduced bone height can prevent long implants (>10 mm long) from being placed because of the risk of involving anatomic structures, such as the maxillary sinuses or inferior alveolar nerve (IAN), during implant placement.

Sinus lifting techniques consisting of a lateral and transcrestal approach for augmenting available bone before implant placement in the posterior maxilla are widely validated in the scientific literature.<sup>1-5</sup> Even though a high survival rate has been reported for both techniques the risk of surgical complication is relatively high, especially regarding sinus membrane perforation, which occurs in 20%–44% of cases with a lateral approach. Complications are also frequently reported with the transalveolar technique, though the rate of membrane perforation rate might be underestimated because the latter is a blind technique.<sup>6</sup> In fact, it was reported that membrane injuries during transalveolar technique cannot be clinically detectable.<sup>7</sup> Other complications include postopera-

tive infection and total graft failure, which occur in <3% of cases as described in the literature.<sup>2</sup> Knowledge of maxillary sinus anatomic features and a careful preoperative evaluation are important for preventing such complications.<sup>8</sup>

While evaluating treatment alternatives for rehabilitation of the posterior mandible the distance between the bone crest and the IAN is a key factor that can limit treatment options. In cases of inadequate bone volume many surgical procedures can be adopted to augment the volume in the posterior inferior jaw. Vertical bone augmentation through guided bone regeneration has been proposed, even though only a few studies have reported the results of this approach.<sup>9</sup> Reduced bone height can also make the surgical procedure difficult to perform. Moreover, use of autogenous bone block graft should be evaluated, taking into account the adverse sequelae that can follow the harvesting procedure.<sup>10</sup> The incidence of complications is relatively high, and accurate preoperative planning and examination are required to reduce the incidence.<sup>11,12</sup> Other techniques, such as IAN transposition, should be considered carefully because of the relatively high risk of injury during the surgical procedure.<sup>13-15</sup> Furthermore, the longer rehabilitation times usually necessary after augmentation procedures should be considered when evaluating treatment alternatives.

The use of short implants has been suggested as an alternative to bone augmentation for the rehabilitation of edentulous jaws, particularly in the posterior areas. Short implants have been defined as those shorter than 11 mm,<sup>16</sup> shorter than 10 mm,<sup>17</sup> or shorter than 8 mm.<sup>18</sup> In the latter case the authors considered only the portion of the implant inserted into the bone, which must be  $\leq 8$  mm, instead of the actual length of the implant.<sup>18</sup> Though some reports have correlated

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the use of short implants with unpredictable outcomes,<sup>19,20</sup> more recent reviews showed better clinical results for these kind of rehabilitations.<sup>21,22</sup> Also, in the long-term, even though several prosthetic complications have been reported, a high survival rate was described for short implants placed in posterior areas of the jaws.<sup>23</sup>

The aim of this prospective study was to assess the clinical and prosthetic performance of short implants supporting mandibular and maxillary rehabilitations and to evaluate marginal bone resorption after 1 year of loading.

## MATERIALS AND METHODS

This prospective single-cohort study was designed and conducted following the principles of the World Medical Association Helsinki Declaration of 1975 for biomedical research involving human subjects, as revised in 2000.<sup>24</sup> Ethical approval for the study was obtained by the review board of the IRCCS Istituto Ortopedico Galeazzi. All patients were informed about the study aims and design and gave written informed consent.

Patient inclusion criteria were the following:

- Partial of full edentulism in either maxilla or mandible
- Impossibility of placing an implant  $\geq 10$  mm without any prior bone grafting procedure as independently assessed by 2 clinicians (S.T. and S.C.) during treatment planning; if there was no agreement about the possibility of placing a longer implant, the case was excluded from the study
- At least 18 years old
- Absence of general medical contraindications for oral surgery procedures (American Society of Anesthesiologists 1 or 2; <http://www.asahq.org/For-Members/Clinical-Information/ASA-Physical-Status-Classification-System.aspx>)
- Full-mouth bleeding score and full-mouth plaque score  $< 25\%$  at baseline
- Ability to sign the informed consent form

Patients were not enrolled in the study if they had one of the following exclusion criteria:

- Any disease or condition that might compromise or negatively influence tissue healing and osseointegration, such as hematologic disease, disease of the immune system (eg, autoimmune diseases or acquired immunodeficiency syndrome), uncontrolled diabetes, metabolic disease affecting bone, pregnancy, or lactation
- Inability or unwillingness to return for follow-up visits
- Inability or unwillingness to maintain a good level of oral hygiene

Inclusion and exclusion criteria were verified after diagnosis and before definitive treatment planning by one of the authors (S.C.). One experienced surgeon with  $> 10$  years of experience in implant surgery (S.T.) performed all the surgeries.

In total, 54 implants  $< 10$  mm were placed in 42 patients from February 2009 to November 2011. The surgeries were performed in a private office and a university clinic using the same equipment and in comparable surgical settings. One patient failed to attend the 12-month follow-up visit and was

Length (mm)	Diameter (mm)					Total
	3.5	3.75	4	4.5	5	
6.5	0	0	11	0	0	11
7.5	0	0	3	0	0	3
8.5	0	2	27	7	3	39
Total	0	2	41	7	3	53

excluded from the data analysis. Hence, the present article reports data for 53 implants, placed in 41 patients (22 women and 19 men; mean age,  $55.7 \pm 12.3$  years). Implant characteristics are summarized in Table 1. Follow-up periods ranged from 6.2 to 41.7 months after surgery (mean,  $15.4 \pm 10.3$  months).

## Surgical and prosthetic procedure

Antibiotic prophylaxis with amoxicillin 2 g was administered to all patients 1 hour before surgery in all patients. All implants were placed in healed sites and the bone socket was prepared using a standard atraumatic technique with a sequence of drills of increasing diameter at the decided length. The implant site was always underprepared, taking in consideration the bone density. All implants (BTI Biotechnology Institute, Alava, Spain) had a microtextured surface and a conical shape. Shorter implants (6.5 mm) had a straight, noncutting, apex shape. They were all placed with at least 25 Ncm torque to obtain adequate primary stability. All short implants were wet with liquid pure platelet-rich plasma (P-PRP) and prepared using the protocol described elsewhere.<sup>25</sup>

After implant placement, the flap was repositioned and sutured with 5-0 (Ethicon Inc, Johnson & Johnson, Piscataway, NJ) nonabsorbable sutures. Activated liquid P-PRP was sprayed onto or was injected at the suture site with the aim of enhancing primary soft tissue closure and further healing. Postsurgical instructions were provided to patients to control bleeding and avoid detaching sutures during the first healing period. Sutures were removed after 10 days.

A provisional restoration, made by composite resin (GC Gradia, GC Corporation, Tokyo, Japan), was delivered after a 5-month healing period for maxillary implants and after 3 months for mandibular implants. Immediately after placement the provisional restoration was not occluding. In the following 3 months, progressive loading was accomplished through monthly apposition of composite resin on the occlusal surface, achieving contact with the opposite occlusal surfaces after 2 months. After 3 months the provisional prostheses were substituted with the final prostheses made of metal-reinforced composite or metal-ceramic crowns. Composite crowns were applied when an opposite composite prosthesis (composite restorations or removable prosthesis) was present to avoid excessive abrasion over time. In all other cases metal-ceramic crowns were placed. Implant abutments all had internal connections. Platform switching was not applicable for 6.5-mm implants, but it was about 0.35 mm for longer implants, respecting the limitations of the abutment manufacturer (BTI Biotechnology Institute).

### Clinical and radiological evaluation

Clinical evaluation was performed every 6 months for the first 2 years then yearly. Survival and success rates were evaluated and recorded, following the definitions and parameters described elsewhere.<sup>26,27</sup> Any surgical, prosthetic, or clinical complication was recorded. Prosthetic success was evaluated as follows: prosthesis in function, without mobility and pain, even if in the face of the loss of one or more implants. Radiographic evaluation was performed through the use of periapical radiographs with individualized holders to measure marginal bone loss around implants over time in comparison with the bone level at the time of provisional prosthesis placement (baseline). Measurements were performed with ImageJ version 1.46 (National Institutes of Health, Bethesda, Md).

### Data analysis

In this ad interim report, 1-year data regarding bone resorption were assessed. Implant survival and success rates were evaluated by comparing maxillary and mandibular implants, splinted and single implants, and implants of different lengths. A Student *t* test was used to compare bone resorption between mandibular and maxillary implants and splinted and single implants. Analysis of variance was used to compare bone resorption among different implant lengths. Level of significance was placed at  $P < .05$ .

### RESULTS

Implant length and diameter distribution are shown in Table 1. Table 2 summarizes implant positions and prosthetic characteristics. Mean residual bone height was  $6.21 \pm 1.05$  mm in the upper jaw and  $10.73 \pm 1.63$  mm in the mandible, and it was significantly different between the 2 jaws ( $P < .05$ ). No surgical or postsurgical complications were reported.

Overall, cumulative implant survival and success rates were both 100%, and there were no prosthetic or clinical complication. Prosthesis success rate was also 100%.

One year after loading, a mean peri-implant bone loss of  $0.71 \pm 0.23$  mm was recorded; there was no significant difference between mesial and distal measurements ( $P = .79$ ). Maxillary implants had a mean bone loss of  $0.69 \pm 0.24$  mm (Figures 1 and 2). Mandibular implants had a mean bone loss of  $0.73 \pm 0.23$  mm (Figures 3 and 4). The difference between the 2 jaws was not statistically significant ( $P = .59$ ).

All single implants were 8.5-mm long; shorter implants were splinted together or splinted with longer implants (10 mm or 11.5 mm, which were excluded from this study). After 1 year, bone loss around single implants and splinted ones was not significantly different ( $P = .67$ ). Mean bone loss was  $0.73 \pm 0.23$  mm for single implants and  $0.70 \pm 0.23$  mm for splinted implants. No effect of implant abutment characteristics and dimension of platform switching could be evaluated by comparing the 8.5-mm implants with shorter implants in terms of peri-implant bone loss.

The effect on bone resorption of characteristics of the opposing teeth and prosthesis was negligible. Most of the included implants had natural teeth opposing ( $n = 36$ ); the rest

TABLE 2

Implant positions and prosthetic characteristics; anterior implants were implants placed to substitute teeth between 1.5 to 2.5 and 3.5 to 4.5

FDI/(ADA)*	Single	Splinted together	Splinted with longer one	Total
<b>Mandible</b>				
44 (#28)	1	0	0	1
Anterior	1	0	0	1
37 (#18)	0	1	0	1
36 (#19)	2	2	0	4
35 (#20)	1	5	0	6
45 (#29)	0	3	0	3
46 (#30)	4	3	0	7
47 (#31)	2	3	0	5
Posterior	9	17	0	26
Total	10	17	0	27
<b>Maxilla</b>				
14 (#5)	1	0	0	1
23 (#11)	0	0	1	1
24 (#12)	1	0	0	1
Anterior	2	0	1	3
17 (#2)	0	0	2	2
16 (#3)	2	0	3	5
15 (#4)	1	0	4	5
25 (#14)	0	0	1	1
26 (#14)	1	0	4	5
27 (#15)	0	0	4	4
28 (#16)	0	0	1	1
Posterior	4	0	19	23
Total	6	0	20	26

\*Tooth number according to World Dental Federation (FDI) and American Dental Association (ADA) conventions.

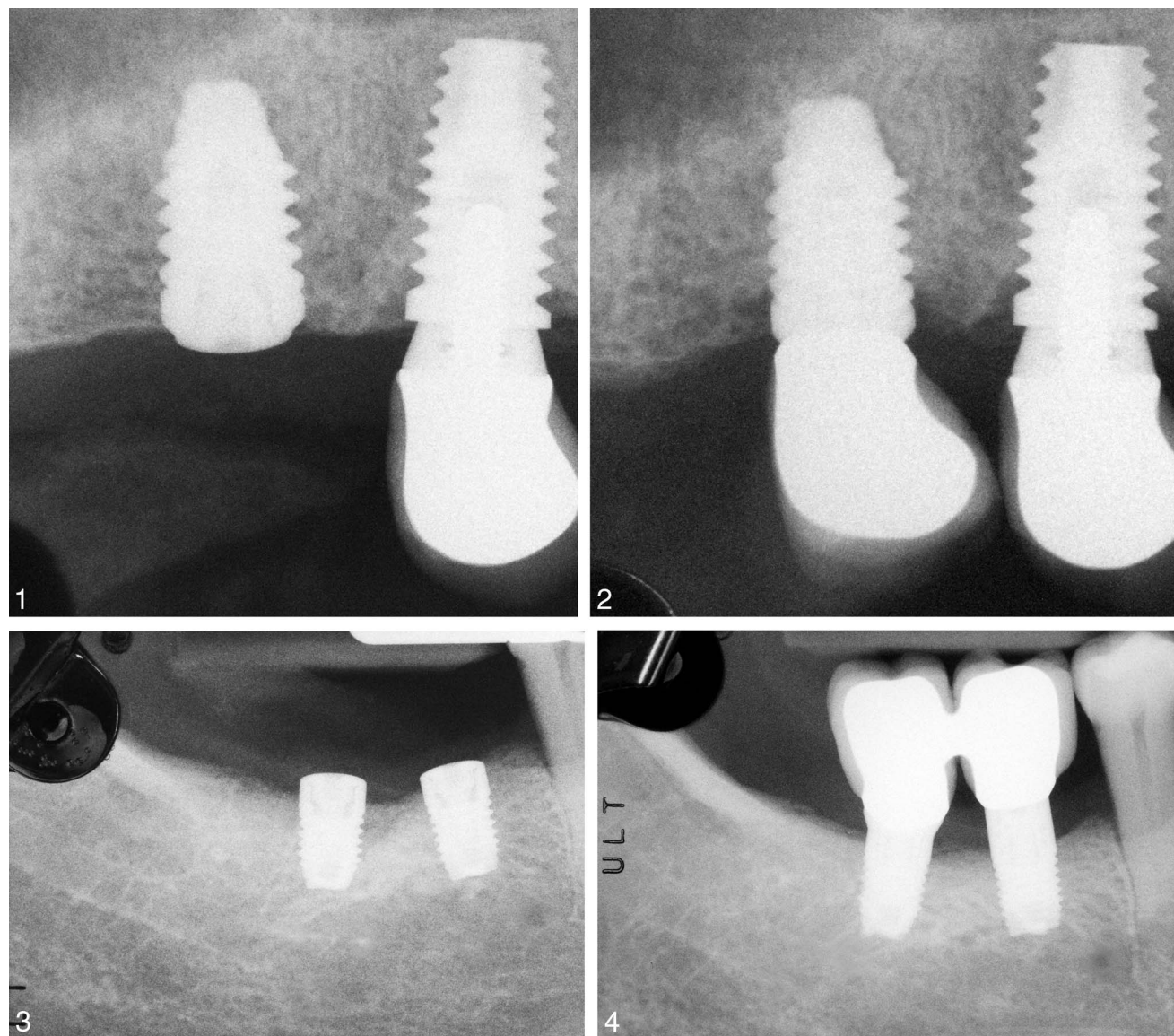
were occluded with teeth-supported prosthesis ( $n = 6$ ), implant-supported prosthesis ( $n = 6$ ), or composite restorations or removable prostheses ( $n = 5$ ). Neither definitive prosthesis material influenced bone loss rate.

### DISCUSSION

The present report showed that short implants may achieve optimal clinical and radiographic outcomes at the 1-year follow-up when used for single restoration or when connected with other implants in substituting for more than one tooth. There was no difference in outcomes between mandibular and maxillary restorations even though a higher quantity of bone volume was required in mandibular restorations because of the need for a safe distance from the IAN as described in previous reports.<sup>28,29</sup>

Several systematic reviews of the literature have evaluated the outcomes of short implants used for the rehabilitation of edentulous jaws. In 2010, Neldam and Pinholt<sup>30</sup> included 27 studies describing implants  $< 9$  mm long. They reported failure rates ranging from 0 to 37.5%, with no significant difference among different implant lengths. They also found that most bone loss occurred during the first year of loading.

In 2011, Pommer and coworkers<sup>22</sup> evaluated the effect of implant length on early failure rates. The meta-analysis reviewed 54 observational studies and 19,083 implants. They observed that shorter implants ( $< 10$  mm long) demonstrated a



**FIGURES 1–4.** **FIGURE 1.** Short implant in the posterior maxilla, placed respecting the anatomy of maxillary sinus floor. **FIGURE 2.** One-year follow-up after definitive prosthetic rehabilitation. It can be seen that the mean marginal bone resorption was 0.78 mm and did not affect implant and prosthesis success. **FIGURE 3.** Short implants in the posterior mandible. **FIGURE 4.** One-year follow-up after definitive prosthetic rehabilitation

higher failure rate than longer implants even though the computed odds ratio was only 1.8. Moreover, considering only rough-surfaced implants, the failure rate was between 0.4% and 1.8% for short implants and between 0% and 1% for longer implants, showing a relevant effect of implant surface on overall survival rate.

In another recent systematic review of short implants, Annibaldi and coworkers<sup>21</sup> reported a cumulative success rate of 99.1% after a mean period of  $3.2 \pm 1.7$  years from 16 studies (6193 short implants). A higher failure rate was reported for the anterior maxilla (mean survival rate = 88.4% in 3 studies); more than half of the considered implants were placed in the posterior mandible ( $n = 3400$ ). The analysis of bone loss found that only one study reported amount of bone resorption over

time, showing that the great majority of implants had no bone loss.<sup>31</sup>

In the present report, the success and survival rates were coherent with those presented in the previously cited systematic reviews, demonstrating that if an accurate surgical protocol is applied, short implants can be a viable treatment alternative in cases of reduced bone height.

Some authors have stated that wetting the implant surface with liquid P-PRP enhances osseointegration and tissue stability over time because the platelet concentrate can stimulate the osteoblasts, creating a bioactive interface.<sup>25</sup> Moreover, P-PRP can allow better soft tissue healing after implant placement and after second-stage surgery. In fact, P-PRP releases factors that are involved in promoting tissue regeneration, such as fibrinogen, fibronectin, platelet-derived growth factor, trans-

forming growth factor- $\beta$ , vascular endothelial growth factors, and others.<sup>32</sup> The concentrate has a marked anti-inflammatory action that suppresses such pro-inflammatory chemokines as interleukin-1<sup>33,34</sup> and has an antimicrobial effect.<sup>35,36</sup> These characteristics, together with the hemostatic properties and high biocompatibility, contributed to the favorable action on soft tissue healing.<sup>37</sup>

The use of short implants should be considered as an alternative to bone grafting procedures in sites where there is insufficient bone for the placement of longer implants. A recent randomized controlled trial (RCT) compared the 3-year outcome of short implants versus sinus augmentation for the rehabilitation of atrophic posterior maxilla.<sup>38</sup> Thirty-four patients per group were treated with a total of 144 implants (73 in the sinus augmentation group and 71 in the short implants group). Two early implant failures were reported after sinus augmentation but only one late failure was described for short implants. Interestingly, only one membrane perforation occurred during the placement of a short implant but 8 perforations were reported during sinus lifting procedures. Even though the reported bone loss for short implants was slightly higher than the loss reported in the present study ( $0.52 \pm 0.43$  mm at 1 year and  $0.71 \pm 0.38$  mm after 3 years) this difference appears to be negligible, and data can be considered similar.

Another RCT compared 7-mm-long implants to vertical augmentation in the rehabilitation of posterior mandibles reporting 1-year results.<sup>39</sup> Thirty patients per group were treated with 61 implants in the augmented group and 60 implants in the short implants group. No statistically significant differences in outcomes were reported even though a higher number of implants failed in the augmented group. No nerve injuries were reported, though 4 wound dehiscences were observed in the augmented group. The mean alveolar bone loss was rather high in both groups 1 year after prosthesis placement ( $1.79 \pm 0.54$  mm for short implants and  $1.65 \pm 0.42$  mm for longer ones in augmented bone).

In summary, such comparative articles showed that short implants can be a good alternative to more demanding augmentation procedures in cases of bone atrophy in the posterior jaw. However, it has to be considered that a lateral approach sinus floor elevation can be successfully performed even in the presence of  $<4$  mm of residual bone height,<sup>1,2,4</sup> while short implants can be placed only in cases where there is enough bone volume to obtain primary stability after implant placement.

Several limitations of the present study should be highlighted. First, the nature of the study was not comparative; hence, the results should be considered carefully when evaluating short implants as a treatment alternative. Furthermore, the follow-up duration could be considered short, though in the literature most failures occurred early during the first 6–9 months after prosthetic loading.<sup>40,41</sup> The relatively short follow-up may have influenced the evidence that there were no differences in bone resorption between splinted implants and single implants and among different opposite occluding surfaces, whose effects can be hypothesized to be observable in longer periods of observations. Moreover, the small sample size and the variability of implant sites may limit

the external validity of the reported results. Finally, most of the implants were 4 mm in diameter and this could have confounded the results, even though it provided a bone-to-implant contact comparable with that of longer but narrower implants.

Despite the limitations of this study, short implants should be considered as a viable treatment alternative for the rehabilitation of edentulous jaws in cases of reduced bone volume. The absence of surgical and postsurgical complications has to be considered in choosing a treatment and should be taken into account in light of the possibility of adverse sequelae related to augmentation procedures. More well-designed RCTs comparing the use of short implants versus augmentation procedures with longer follow-up will help to better understand the clinical performance of the treatment options described in this report.

#### ABBREVIATIONS

IAN: inferior alveolar nerve  
P-PRP: pure platelet-rich plasma  
RCT: randomized controlled trial

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