Ongoing Crestal Bone Loss around Implants Subjected to Computer-Guided Flapless Surgery and Immediate Loading Using the All-on-4® Concept

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ABSTRACT

Background: The All-on-4® concept is widely applied for full-arch rehabilitations, using two tilted and two axially loaded implants in order to overcome anatomical constraints.

Purpose: The aim of this study was to assess the survival and individual success of implants immediately loaded with an All-on-4 full-arch screw-retained prosthetic bridge in fully edentulous mandibles or maxillae over up to 3 years.

Materials and Methods: In total, 20 patients with atrophic jaws (9 maxillae, 11 mandibles) were treated with computer-guided flapless surgery and immediately provided with a provisional bridge. The final prosthesis was delivered after 6 months. In total, 80 TiUnite™ Brånemark implants were placed. Radiographs were taken after surgery and 1 and 3 years later.

Results: A 3-year survival rate of 100% was seen for all implants, both in lower and in upper jaw. None of the temporary or definite prostheses were lost over the follow-up period of 3 years. After 1 year, the mean bone loss was 1.13 mm (SD 0.94; range −0.1 to 3.8), and after 3 years, it was 1.61 mm (SD 1.40; range 0 to 5). The mean bone loss between the 1-year and 3-year follow-ups was 0.48 mm (SD 0.66; range −1.2 to 3.6). This difference was statistically significant (p < .001), indicative of ongoing bone loss. Twenty-six percent of the implants had bone loss above 1.5 mm after 1 year, but after 3 years, 30% of the implants had already lost more than 1.9 mm.

Conclusion: The implant and prosthetic survival was 100%, and patients benefited from the All-on-4 treatment. However, unacceptable ongoing bone loss was seen in 49.2% of the patients; this may be a warning sign for future problems and needs clinical attention. Overloading and surgery-related aspects need to be investigated as potential explanations.

KEY WORDS: All-on-4, bone level, bone remodeling, immediate loading, one-stage surgery, prosthetic complications, success

INTRODUCTION

Today, dental implant treatment is predictable for both total and partial edentulism.¹ Long-term clinical data have in general shown a high survival and success rate

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when sufficient bone volume is available. The restoration of the fully edentulous jaw on four to six axially loaded dental implants was originally proposed by Brånemark et al. and has shown close to 100% implant survival provided the implants are anchored optimally. This ideal placement can be hampered by reduced bone volume or anatomical constraints such as the maxillary sinuses and the presence of the inferior alveolar nerve in the mandible. Various techniques to overcome these problems have been proposed. One of them is the sinus floor augmentation procedure for the maxilla, which has become a standard procedure to increase bone height in the posterior maxilla. For the latter, various grafting materials have been used, with disparities in outcome often more related to the residual crestal bone height than to the grafting material. On the other hand, bone onlay procedures result in unpredictably increased graft bone resorption, and when implants are consecutively installed, these are subject to more peri-implant bone loss and a less predictable treatment outcome.

In the last few years, several clinical studies have reported that tilting of the implants in order to avoid critical anatomical structures such as the sinus or the mandibular nerve represents an acceptable treatment option. Krekmanov and colleagues proposed tilted distal implants to avoid anatomic obstacles and to reduce the length of distal cantilevers. The combination of tilted and axially loaded implants in conjunction with immediate loading was introduced as the All-on-4 concept for the mandible in 2003 and basically refers to the placement of two axially loaded anterior implants and two tilted ones in the posterior zone. The tilted implants are intended to pass the mental foramen and require an angulated abutment. A large cohort clinical study involving 245 patients and 980 implants installed in the mandible revealed patient and implant success rates of 94.8% and 98.1%, respectively, at 5 years. This was reduced to 93.8% and 94.8% after 10 years’ follow-up. This gave a prosthesis survival of 99.2% with a follow-up of up to 10 years. Unfortunately, bone evaluation data were not reported. The All-on-4 concept is also widely applied in the maxilla. Studies have scrutinized its outcome in the maxilla using open-flap surgery as well as using flapless computer-assisted surgery. Despite good implant survival, many of the studies have drawbacks such as a lack of appropriate reporting of bone levels or peri-implant soft tissue health or large dropouts during follow-up.

Some studies have revealed that in partial implant restorations, tilting of the implants does not jeopardize marginal bone resorption in either maxilla or mandible. Whether this is also sustained in cross-arch All-on-4-type reconstructions with cantilevers distal to the posterior tilted implant and whether the bone level is stable over time remain to be investigated. Based on the available clinical studies, the tilted implants are not subject to a higher implant failure rate, but there are indications from in vitro studies that stress patterns around the tilted distal implants depend on the angulation and that this may affect crestal bone remodeling. For the implants placed at angles of 15° or 30°, little difference exists between the angled and axially loaded anterior implants. However, based on an in vitro photelastic stress analysis study, the peri-implant bone around distal abutments placed at an angle of 45° may be more prone to occlusal overload than bone surrounding implants with lesser tilts. This could over time lead to bone level changes, by itself increasing the risk for peri-implant diseases. Thus, it is the more regrettable that in the majority of All-on-4 papers, crestal bone level changes around the implants are reported inconsistently or not at all.

More and more, contemporary implant surgery is performed as guided surgery based on virtual computer-assisted planning, using a flapless procedure. Only two of the All-on-4 concept studies were done using this technique, and unfortunately, both lacked radiographic evaluation. The clinical applicability of this surgical protocol is therefore still unclear.

The aims of the present 3-year prospective case study were the following: (1) to assess the clinical and radiographical outcomes of dental implants placed according to the All-on-4 principle in extreme atrophic bone conditions and immediately loaded; (2) to evaluate individual implant success based on bone level changes from the day of surgery and to compare this between jaws and between tilted and axially loaded implants; and (3) to review the available literature on the All-on-4 concept, especially that related to survival and bone levels.

MATERIALS AND METHODS

Study Protocol

The study was designed as a single-center prospective clinical case series in which patients with an extremely
resorbed maxilla or mandible were enrolled, treated, and followed up for 3 years. The study was approved by the ethical committee of the University Hospital of Ghent, Belgium, under reference code EC UZG 2005/201.

At the first visit, all patients were properly informed of the nature of the study, and written informed consent was obtained. Nobel Biocare® (Göteborg, Sweden) dental implants were used, specifically the Mk III Groovy (diameter 3.75 mm) for the lower jaw and the NobelSpeedy™ Groovy (diameter 4.0 mm) for the upper jaw. The implant length depended on the residual crest height and was decided at the time of planning by means of the NobelGuide™ computer-based planning system. A customized surgical template was fabricated according to the preoperative computer-based 3D plan and was used during the surgical procedure to ensure accurate implant positioning. All implants were placed according to the flapless protocol and immediately loaded by a provisional Procera® implant bridge.

**Selection Criteria**

All patients included in this study were at least 18 years old and in good general health. The opposing dentition had to be natural teeth, an implant-borne fixed restoration, or a removable prosthesis with a corresponding number of teeth to allow direct loading of all implants. If tooth extractions were necessary prior to surgery, they had to be performed at least 8 weeks before implant insertion. Patients with periodontal diseases in the opposing jaw had to be treated and cleared of infection before the start of the implant surgery. Systemic exclusion criteria were as follows: conditions requiring the use of prophylactic antibiotics, chronic use of steroids, a history of leukocyte dysfunction, a history of renal failure, metabolic bone diseases, and HIV infection. Local exclusion criteria were as follows: irradiation therapy (>40 Gy), presence of osseous lesions, unhealed extraction sockets, previous grafting procedures at the implantation site, and persisting intraoral infection due to inadequate oral hygiene or motivation.

**Presurgical Procedure**

All patients received a newly fabricated, perfectly adapted removable prosthesis. These prostheses were marked with eight marker points before the scanning procedure. A putty bite registration in maximal occlusion, referred to as the radiographic guide, was made of each patient prior to scanning (Figure 1A). The patients were double-scanned following the All-on-4 protocol. The first CT scan taken was of the patient with the prosthesis and putty guide correctly placed in the mouth. A second CT scan was taken of only the prosthesis.

Based on the CT scan, every patient’s surgery was virtually planned with the NobelGuide software, resulting in an individualized surgical template. All planning was performed by the same person and checked by the prosthodontist. A new bite registration, using the surgical guide, was performed on an articulator in the dental laboratory to fabricate a surgical index. This surgical index was necessary to ensure exact positioning of the surgical template in the mouth before starting surgery (Figure 1B). To facilitate the insertion of the multiunit abutments placed at 30° angles at time of surgery, a jig construction connecting the abutment and the distal implant on each site was prefabricated in the dental lab. The jig construction included an impression coping for open-tray impression on the axial implant and a 30° multiunit nonengaging abutment and abutment holder with jig stabilizer on the tilted implant.

**Surgery and Provisionalization**

Surgery was performed under local anesthesia with articaine hydrochloride with adrenaline (1:100 000). Patients were not premedicated. All patients were treated by the same maxillofacial surgeon (HB), who had experience with the implant system used. They received four dental implants located anterior to the mental foramen or the sinus (Brånemark System, Nobel Biocare). All implants were placed flaplessly using the NobelGuide surgical template (Figure 1C). The two most distally placed implants were tilted up to 30°, with placement carefully chosen to avoid damage to the inferior alveolar nerve or perforation into the maxillary sinus. These distal implants emerged, after connecting the 30° multiunit abutments, in the second premolar region, so that a definitive bridge with a minimal cantilever length of 1 (pre)molar length could be installed. No cantilevers were provided on the provisional bridge. The two medial axial implants were placed at the lateral incisor position.

Bone density was evaluated at time of drilling by the surgeon. A torque controller (Osseeocare, Nobel Biocare) with a torque limit of 50 Ncm was used during implant placement, and a manual wrench was used in case of incomplete seating of the implant.
Thirty-degree multiunit abutments were connected using a jig construction, prefabricated in the lab, to the most distal implants. Straight (0°) multiunit abutments were provided on the two medial axial implants, or impressions were taken at fixture level. The temporary prosthesis was prepared in advance, with access holes allowing fixation of the temporary cylinders. Within 48 hours, a 10-unit provisional fixed prosthesis was connected to the implants. The occlusion was checked and hygiene instructions were given to the patient.

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Crestal Bone Loss Evaluation
Crestal bone levels were evaluated via periapical radiographs taken at regular follow-up visits. The baseline for all measurements was after functional loading with the provisional bridge, maximally two days after implant placement. A conventional Rinn® XCP film holder (Dentsply, Elgin, IL, USA) was used, and its position was adjusted manually to be approximately orthogonal. Due to the high degree of alveolar ridge resorption, it was difficult to obtain an orthogonal placement of the holder in some patients. An independent researcher (CR), not involved in the actual patient treatment,
performed the radiographical analyses based on anonymized patient files. Bone level measurements were done via periapical radiographs using AxioVision (release 4.8, Zeiss, Oberkochen, Germany), with a standard deviation of 0.1 mm. The bone loss was calculated as the difference between the bone level at a certain point in time and the bone level at baseline (placement of provisional implant). Mesial and distal bone loss were measured, and the Wilcoxon signed-rank test was applied to test the differences between the mesial and distal bone level measurements. Because these were not statistically significantly different \( (p = .550) \), the mesial and distal values were averaged to obtain one crestal bone level value per implant.

**Statistical Analysis**

Data analysis was executed by an independent examiner (CR) not involved in the actual patient treatment and was based on anonymized patient files. Statistical calculations were done using SPSS 18.0 (IBM, Armonk, NY, USA) with the level of significance set at 0.05. The Friedman test was used to evaluate bone loss changes over different time intervals. If significant, the Wilcoxon signed-rank test was used for bone loss comparison between time intervals. The \( \chi^2 \)-test was used to determine differences in implant success between groups.

One week after the initial measurements, 10 radiographs were chosen at random and remeasured by the independent researcher and the practitioner to obtain intervariability and intravariability. The \( t \)-test was applied, and no statistically significant difference was found \( (p > .265) \) The Mann-Whitney \( U \)-test was used to evaluate crestal bone loss and individual implant success rates over time. The data for actual bone loss from the time of implant placement to 1 year and 3 years after placement were used for statistical analysis and examined using the Friedman test. This test revealed a significant overall \( p \) value; hence, bone levels at different time points were compared one-to-one using the Wilcoxon signed-rank test. The individual success of each dental implant was calculated arbitrarily, as proposed by Vandeweghe and De Bruyn.\(^{22}\) By and large, an individual implant was considered a success when no more than 1.5 mm of bone remodeling took place during the first year and no more than 0.2 mm yearly thereafter. Basically, this meant an implant could lose a total of 1.9 mm after 3 years and still be called a success. A multivariate analysis (mixed-model) to examine differences in bone loss between implants in the upper and lower jaw and between straight and tilted implants was performed.

**Literature Search**

The existing evidence on the All-on-4 concept was scrutinized via an electronic search using PubMed. All relevant papers published in English from 2000 to 2012 concerning the All-on-4 concept as applied in fully edentulous jaws were considered. Inclusion or search terms were as follows: “All-on-4 concept,” “bone loss and tilted implants,” “immediate function on 4 implants,” and “axial and tilted implants.” All articles reporting on earlier or simultaneous grafting procedures, zygoma implants, or isolated clinical cases were excluded, and only human studies were retained.

**RESULTS**

**Patients and Implants**

In total, 80 implants were installed: 37 of 15 mm in length, 40 of 13 mm, 2 of 11.5 mm, and 1 of 10 mm. The diameter was 4.0 mm in 42 implants and 3.75 mm in 38. Of the 20 patients, 14 were women and 6 were men, and the mean age was 55 years (range 35–74). Each patient received four implants, of which the two distal implants were tilted between 20° and 40° according to the anatomical conditions, and the two mesial implants were oriented axially. Nine maxillary arches and 11 mandibles were treated. All implants were installed according to the manufacturer’s guidelines. After 3 years all implants survived.

All patients received a 10-unit provisional bridge the day after surgery, and this was functionally loaded for at least 3 months. No complications such as fractures occurred during the surgical phase or the delivery of the immediate restoration. The final prosthetic work was performed by the referring dentist. After 3 years, all structures were still functional, although signs of abrasion and acrylic discolorations were present.

Periapical radiographs were available for 16 out of 20 patients at baseline and after 1 and 3 years (20% radiographic dropout). The radiographs from 4 patients were classified as unreadable due to misalignment at one or more time points. Additionally, three implant radiographs from the 3-year follow-up were unreadable. Hence, 61 implants (76% of the material) were taken into account for statistical analysis of bone level changes.
The mean bone loss between the 1-year and 3-year follow-ups was 0.48 mm (SD 0.66; range −1.2 to 3.6). This difference was statistically significant \( p < .001 \), indicative of ongoing bone loss (Figure 2). A multivariate analysis (mixed-model) to examine differences in bone loss between implants in the upper and lower jaw and between straight and tilted implants showed that bone loss was not significantly different between implants placed in the maxilla and those placed in the mandible \( p = .281 \) or between straight and tilted implants \( p = .605 \) after 3 years (Table 1, Figures 4 and 5).

Twenty-six percent of the implants had bone loss above 1.5 mm after 1 year, but after 3 years 30% of the implants had already lost more than 1.9 mm. Hence, a large proportion of the implants showed continuous crestal bone loss. Radiographs of the worst and best cases regarding bone loss after 3 years of loading are shown in Figure 3. For the maxilla, the individual implant success after 1 year was 56%, significantly lower \( p < .001 \) compared with the mandible (90%). Three years after surgery, individual success was 58% for the maxilla and 81.8% for the mandible.

### Table 1: Overview of Bone Loss and Implant Success at 1 and 3 Years’ Follow-Up

<table>
<thead>
<tr>
<th>Jaw</th>
<th>Bone Loss (mm), Mean ± SD (Range)</th>
<th>Implant Success (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Year</td>
<td>3 Years</td>
</tr>
<tr>
<td>Overall</td>
<td>1.13 ± 0.94 (−0.1–3.8)</td>
<td>1.61 ± 1.40 (0–5)</td>
</tr>
<tr>
<td>Maxilla</td>
<td>1.58 ± 1.22 (0–3.80)</td>
<td>1.89 ± 1.29 (0–5)</td>
</tr>
<tr>
<td>Mandible</td>
<td>0.82 ± 0.51 (−0.10–2.30)</td>
<td>1.42 ± 0.69 (0.30–3.99)</td>
</tr>
<tr>
<td>Tilted</td>
<td>1.13 ± 0.71 (0–3.20)</td>
<td>1.55 ± 0.73 (0.45–3.50)</td>
</tr>
<tr>
<td>Straight</td>
<td>1.14 ± 1.14 (−0.10–3.80)</td>
<td>1.67 ± 1.22 (0–5)</td>
</tr>
</tbody>
</table>

Implant success was defined as bone loss of ≤1.5 mm and ≤1.9 mm after 1 and 3 years, respectively.
maxilla and 82% for the mandible ($p < .021$). Again, this is indicative of ongoing bone loss in both jaws because the success criteria used allowed for an additional loss of 0.4 mm. When comparing straight and tilted implants, no significant differences in success rate could be observed at 1-year ($p = .386$) or 3-year ($p = 1.000$) follow-up (Figures 4 and 5). In addition, multivariate analysis was done to examine differences in success and revealed no statistically significant differences between jaws ($p = .278$) or between angulations ($p = .881$).

The purpose of the literature search was to get an idea of the usual clinical outcome, as well as of reported crestal bone levels, giving insight into implant survival as well as success over time and in the long term. The outcome of this review is summarized in Table 2.

In all articles, bone loss was measured via either intraoral radiographs or panoramic radiographs. Only one article, however, reported outcomes after a follow-up time of 10 years; three articles described 5 years of follow-up. The TiUnite™ implant system was most commonly used, accounting for 5523 out of a total of 6055 reported implants. It was usually placed using conventional flap surgery with mucosal incision. Only two publications reported on flapless guided surgery, including crestal bone loss data after 1 year. Only 4 out of 19 papers reported on bone loss over a 3-year period; one of the articles reported on only 9 out of 133 implants placed in the maxilla. There seems to be no significant difference in peri-implant bone loss between axially loaded and tilted implants. The least one can say is that this extremely large dropout is highly suggestive of selection bias.

**DISCUSSION**

The current study is a prospective study evaluating the clinical survival and crestal bone changes for implants placed using computer-guided surgery in conjunction with immediate loading. An overall implant survival of 100% was achieved, which is in line with similar reports on immediate loading in fully edentulous maxillae and mandibles. In terms of survival of implants and prosthetic reconstructions, the results of applying the All-on-4 immediate function concept in completely edentulous jaws are predictable.

It is tempting to conclude from the existing literature that implant survival is well reported for the All-on-4 concept, but data on implant success based on crestal bone level evaluation are inconclusive, especially for the long run. In this respect, our clinical study presented in this paper is the first to report crestal bone loss data 3 years after implant restoration using a flapless and stereolithographic guided-surgery approach. The clinical outcome of 100% implant survival is in line with available literature. Agliardi and colleagues found 98.4% survival in the maxilla and 99.7% in the mandible.
after up to 5 years of loading. In a systematic review where 470 immediate rehabilitations were analyzed, no differences in terms of survival were found between maxilla and mandible or between tilted or straight implants in either arch.

In the present report, the mean marginal bone level (1.13 mm) after 1 year of functional loading was comparable with the values found in previous studies on the same type of implant. Although one would expect stability of crestal bone level after the first year of loading, our data clearly show continuous crestal bone loss during the 3 years of follow-up. Between the first and third years, 49.2% of the implants lost more than 0.4 mm crestal bone. These low success rates contradict those normally found in the literature for conventional implant treatment protocols. However, several studies lack reports of bone level, thus providing suboptimal insight into implant success.

The tilting of the implants did not seem to result in differences in peri-implant bone level between the mesial and distal sides of the implants or compared with the upright implants. In this study, the most posterior implants were not tilted more than 30°, because previous studies have shown that implant placement at a 45° angle markedly increases the fringe concentrations, resulting in more occlusal overload and more peri-implant bone loss. In addition, Almeida and colleagues demonstrated in a recent finite element analysis study that two vertical and two tilted implants caused more stress in the bone compared with four vertical implants. This could lead to overload and might explain the continuous bone loss that was observed over time. Aparicio and colleagues described a cumulative success rate of 95% for tilted implants and 91% for axially loaded implants, and no significant difference in marginal bone loss was observed during the following years (up to 5 years' follow-up). In addition, no differences in bone loss between axially loaded and tilted implants have been found in other studies, which supports the findings of our study.

As the study contained no control group, it was difficult to determine the effect of the flapless procedure. However, there have been several studies that compared...
<table>
<thead>
<tr>
<th>Reference</th>
<th>Total No. Patients</th>
<th>Total No. Implants (Mx/Md)</th>
<th>Implant System</th>
<th>Type of Surgery*</th>
<th>Follow-Up (Months), Mean (Range)</th>
<th>Prosthetic Success (%)</th>
<th>Implant Survival (%), Year 1 (Mx/Md)</th>
<th>Bone Loss (mm), Year 1, Mean ± SD (No. Implants)</th>
<th>Bone Loss (mm), Year 3, Mean ± SD (No. Implants)</th>
<th>Bone Loss (mm), Year 5, Mean ± SD (No. Implants)</th>
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<tbody>
<tr>
<td>Malo et al. (2003)</td>
<td>44</td>
<td>176 loaded, 62 unloaded (0/176)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>NR (6–24)</td>
<td>100</td>
<td>100</td>
<td>D 96.7, R 98.2</td>
<td>D 1.2 ± 1.2, R 0.6 ± 0.6 (128)</td>
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<td>32</td>
<td>128 (128/0)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>NR (6–12)</td>
<td>NR</td>
<td>97.6</td>
<td>0.9 ± 1.0 (125)</td>
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<td></td>
</tr>
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<td>Malo et al. (2007)</td>
<td>23</td>
<td>92 (72/20)</td>
<td>TiUnite</td>
<td>Flapless</td>
<td>13 (6–21)</td>
<td>NR</td>
<td>97 (97/100)</td>
<td>1.9 ± 0.9 (36)</td>
<td>NA</td>
<td></td>
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<td>Francetti et al. (2008)</td>
<td>62</td>
<td>248 (0/248)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>22 (6–43)</td>
<td>100</td>
<td>100</td>
<td>A 0.7 ± 0.4, T 0.7 ± 0.5 (176)</td>
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<tr>
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<td>24</td>
<td>96 (0/96)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>32 (19–47)</td>
<td>100</td>
<td>100</td>
<td>A 0.9 ± 0.4, T 0.8 ± 0.5 (68)</td>
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<td>19</td>
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<td>NR (6–12)</td>
<td>NR</td>
<td>97.6</td>
<td>0.9 ± 1.0 (125)</td>
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<td>12</td>
<td>23</td>
<td>TiUnite</td>
<td>Flapless</td>
<td>13 (6–21)</td>
<td>NR</td>
<td>97 (97/100)</td>
<td>1.9 ± 0.9 (36)</td>
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<td>11</td>
<td>62</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>22 (6–43)</td>
<td>100</td>
<td>100</td>
<td>A 0.7 ± 0.4, T 0.7 ± 0.5 (176)</td>
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<td>173</td>
<td>692 (404/288)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>27 (12–59)</td>
<td>NR</td>
<td>99</td>
<td>0.9 ± 0.7, Mx 1.2 ± 0.69 (204)</td>
<td>Mx 1.0 ± 0.7, Md 1.2 ± 0.69 (292)</td>
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<td>Rinne et al. (2010)</td>
<td>37</td>
<td>148 (76/72)</td>
<td>Nanotite (Implant)</td>
<td>Open-flap</td>
<td>12</td>
<td>100</td>
<td>NR</td>
<td>A 0.82 ± 0.31, T 0.76 ± 0.49 (141)</td>
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<td>Malo et al. (2011)</td>
<td>245</td>
<td>980 (0/980)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>NR</td>
<td>NR</td>
<td>96.7</td>
<td>NR</td>
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<td>Jensen et al. (2011)</td>
<td>10</td>
<td>20 (0/20)</td>
<td>NR</td>
<td>Open-flap</td>
<td>12</td>
<td>100</td>
<td>NR</td>
<td>1–2 (19)</td>
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<td>165</td>
<td>708 (0/708)</td>
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<td>Open-flap</td>
<td>29</td>
<td>100</td>
<td>99.6</td>
<td>0.83 ± 0.14 (NR)</td>
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<tr>
<td>Landazuri-Del Barrio et al. (2011)</td>
<td>16</td>
<td>64</td>
<td>TiUnite</td>
<td>Flapless</td>
<td>12</td>
<td>NR</td>
<td>90</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crespi et al. (2012)</td>
<td>36</td>
<td>176 (96/80)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>36</td>
<td>100</td>
<td>NR</td>
<td>Mx + A 1.0 ± 0.35, Mx + T 1.05 ± 0.32 (176)</td>
<td>Mx + A 1.1 ± 0.45, Mx + T 1.12 ± 0.35 (176)</td>
<td></td>
</tr>
<tr>
<td>Galindo and Butura (2012)</td>
<td>183</td>
<td>732 (0/732)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>12</td>
<td>98.9</td>
<td>99.86</td>
<td>NR</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Malo et al. (2012)</td>
<td>242</td>
<td>968 (968/0)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>NR</td>
<td>NR</td>
<td>98.3</td>
<td>NR</td>
<td>1.52 ± 0.3 (621)</td>
<td>1.95 ± 0.4 (106)</td>
</tr>
<tr>
<td>Malo and Lopes (2012)</td>
<td>142</td>
<td>227 (133/94)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>26 (1–107)</td>
<td>NR</td>
<td>96</td>
<td>Mx 1.3 ± 0.4, Mx 1.4 ± 0.3 (88, 53)</td>
<td>Mx 1.6 ± 0.4 (9)</td>
<td></td>
</tr>
<tr>
<td>Cavalli et al. (2012)</td>
<td>34</td>
<td>136</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>40 (12–37)</td>
<td>NR</td>
<td>100</td>
<td>NR</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Grandi et al. (2012)</td>
<td>47</td>
<td>188</td>
<td>JDEvolution</td>
<td>Open-flap</td>
<td>18</td>
<td>100</td>
<td>100</td>
<td>A and T 0.58 ± 0.11</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Francetti et al. (2012)</td>
<td>47</td>
<td>196 (64/132)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>Mx 33.8 (22–40), Md 52.8 (30–66)</td>
<td>100</td>
<td>100</td>
<td>A 0.51 ± 0.17, T 0.39 ± 0.18 (48)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Weinstein et al. (2012)</td>
<td>20</td>
<td>80 (0/80)</td>
<td>TiUnite</td>
<td>Open-flap</td>
<td>30.1 (20–48)</td>
<td>100</td>
<td>100</td>
<td>A 0.6 ± 0.3, T 0.7 ± 0.4 (72)</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

*Open-flap: A mucoperiosteal flap was raised, and the provisional prosthesis or a special edentulous guide (designed by Malo) was used to determine the optimal position and angulation of each implant. Flapless: No mucosal incision was performed, or no flap was raised; a 3D guidance plate was used. Mx, maxilla; Md, mandible; D, developmental; R, routine; A, axially loaded; T, tilted; NR, not reported; NA, not applicable.
flapless with conventional surgery, and they found no significant differences in bone loss between the two procedures. While flapless surgery might reduce postoperative swelling and discomfort, drilling through the soft tissue results in less keratinized tissue, which might hamper aesthetics.

According to a recent review, the accuracy of guided implant surgery in vivo ranges from 0.95 to 4.5 mm at the apex of the implant. Consequently, a small deviation in the positioning of the implants might alter the thickness of the buccal or lingual cortical bone and thus result in additional bone loss. However, as implants were placed without raising a flap, this was difficult to check.

The implants used in this study had a macrogroove in the flank of the thread and oxidized-surface treatment up to the top, including the implant collar (TiUnite Groovy). This macrogroove increases the shear load and adhesion at the bone-implant surface, while the roughened implant collar helps to maintain the bone. Li and colleagues used the Groovy and an ungrooved design and found no difference in survival rate. Pozi and colleagues reported 1.1 mm bone loss after 1 year with the NobelSpeedy Groovy implant, which was significantly more compared with the NobelActive™ implant. Some authors have compared the performance of the different implant designs when the All-on-4 concept is used, but unfortunately, they did not analyze differences in bone loss between the Groovy and ungrooved implants. However, in a systematic review on the All-on-4 concept, Patzelt and colleagues found no association between bone loss and the implant type used.

Studies have shown that a roughened implant neck, with or without a microthread, may help to reduce peri-implant bone loss. However, when the implant surface is exposed to the oral environment, it is highly susceptible to plaque adhesion, which may lead to peri-implantitis. Albouy and colleagues evaluated the progression of peri-implantitis at different implant surfaces and found more bone loss around the TiUnite implants, concluding that patients with implants with this surface are more susceptible to peri-implantitis. According to some authors, patients with TiUnite implants show more bone loss during the first year but enter a steady state thereafter. Despite this early bone loss, a good long-term clinical outcome can be obtained with this type of implant.

**CONCLUSION**

The implant and prosthetic survival was 100%, and patients benefited from the use of the All-on-4 treatment concept. However, unacceptable ongoing bone loss may be a warning sign of future problems and needs clinical attention. Overloading and surgery-related aspects need to be further investigated as possible explanations.

**REFERENCES**

11. Francetti L, Agliardi E, Testori T, Romeo D, Taschieri S, Fabbro MD. Immediate rehabilitation of the mandible with fixed full prosthesis supported by axial and tilted implants:
13. Pomares C. A retrospective study of edentulous patients rehabilitated according to the “all-on-four” or the “all-on-six” immediate function concept using flapsless computer-guided implant surgery. Eur J Oral Implantol 2010; 3: 155–163.


