Split-crest and immediate implant placement with ultra-sonic bone surgery: a 3-year life-table analysis with 230 treated sites

Key words: immediate implant, piezosurgery, split-crest, ultra-sonic bone surgery

Abstract: Ultra-sonic bone surgery (USBS) has been recently introduced as a novel osteotomic technique. This clinical study reports on the application of this new technique to perform ridge-split procedures. Over a period of 3.5 years, 57 patients underwent a split-crest procedure with the aim to place 230 implants, 78 in the mandible and 152 in the maxilla, in order to rehabilitate nine full arches, three hemi-arcades, 43 partial bridges and 24 single crowns. The initial ridge width varied between 1.5 and 5 mm, average was 3.2 mm. The final width of the ridge ranged from 4 to 9 mm, average was 6 mm. The split length varied between 4.5 and 40 mm, average was 15 mm. Inserted implants were 3.25–5 mm in diameter however most of them (82.4%) were standard implants of 3.75 mm; implant length was classically 10–13 mm. Two hundred and twenty-eight (99.1%) out of the 230 planned implants were placed, the two non-suitable sites were in the maxilla. In the mandible, the ridge augmentation procedure was drastically eased by performing a basal longitudinal discharge notch. At second stage surgery, eight implants failed to osseointegrate; the success rate for the placed implants was 96.5%. All implants have been loaded for at least 2 months and no implant was lost after loading. One hundred and eighty-one and 77 implants have been loaded for at least 6 and 12 months, respectively. The 3-year life-table analysis of loaded implants showed a cumulative survival rate of 100%. The split-crest procedure performed with USBS showed to be safe and comfortable.

Osseointegration of dental implants is highly predictable when implants are completely embedded into bone [Bränemark et al. 1977]. A minimal amount of surrounding bone is necessary at implant placement. In the horizontal dimension, an optimal thickness of vestibular and buccal surrounding bone lamellae is $\geq 1$ mm [Nedir et al. 2004]. Nevertheless, narrower lamellae are compatible with implant integration as far as the implant is surrounded by bone [Nedir et al. 2004]. When the alveolar ridge is narrower than the optimally planned implant diameter, onlays of bone grafting material [Marx et al. 1998; Chiapasco et al. 1999; Fiorellini & Nevins 2003] or guided bone regeneration (GBR) are indicated [Nevins & Mellonig 1992; Hammerle et al. 2002]. These methods present several drawbacks; for bone grafting, the latter are: (1) the surgery to gain bone material is invasive, (2) the grafting material resorbs consistently with time [Chiapasco et al. 1999], (3) implantation is delayed because integration of the grafting material requires 3–6 months of healing. For GBR procedures, the drawbacks are: (1) membrane collapse can occur and the expected volume augmentation is not obtained [Nystrom et al. 1996; Chiapasco et al. 1999], (2) membrane can be exposed and further infected [Nevins &
Melloni 1992; Rominger & Triplett 1994; Chiapasco et al. 1999), (3) treatment cost is increased (Chiapasco et al. 1999), (4) implantation is delayed.

To treat narrow alveolar ridges, an alternative approach to bone grafting and GBR has been developed. It consists in splitting the vestibular and buccal cortical tables (Simion et al. 1992; Scipioni et al. 1994) and further open the space with Summers ostotomes (Summers 1994). This creates room for implant placement with sufficient surrounding bone. Splitting is classically performed with chisel and hammer (Coatoam & Mariotti 2003; Olkarinen et al. 2003; Basa et al. 2004), with rotating (Coatoam & Mariotti 2003; Basa et al. 2004) or oscillating saws (Khouri et al. 2000; Zijderveld et al. 2004). The use of bone chisel traumatizes and stresses the patient. Fine tuning of the splitting can be difficult when the crest is dense, especially in the mandible. Rotating and oscillating instruments are time-effective and less stressing for the patient. For the surgeon however, the risk of encroaching the gingiva, the lips or the tongue limits the accessibility and complicates the procedure.

Ultra-sonic bone surgery (USBS) represents a novel alternative technique; it has been recently introduced to perform precise bone surgery (Torella et al. 1998; Vercellotti 2000; Vercellotti et al. 2001; Blus & Szumukler-Moncler 2004). Ultra-sounds are extensively used in medicine and surgery. They are in daily use as a diagnosis tool in echography; they permit removal of dental caries and biopsy sampling.

Clinical studies involving USBS have been scarcely reported, only few cases have been published so far by other groups (Torella et al. 1998; Vercellotti 2000; Vercellotti et al. 2001). The purpose of this paper was to document the application of USBS to the split-crest procedure with immediate implant placement over a 3.5-year period with a larger number of treated sites.

Material and methods

USBS device
The piezo-surgery (PS) device (Mectron, Genova, Italy) and the UBS device (Italia Medica, Milano, Italy) were used. The PS works in the 24–29 kHz range and the power varies from 5 to 16 W (Robiony et al. 2004). The UBS works in the 20–33 kHz range and the maximum ultrasound power is 90 W.

Inclusion criteria
Patients were treated with the present modality if: (1) implant therapy was the elective treatment to restore partial or total edentulism, (2) the alveolar ridge width was inferior to the optimally planned implant diameter (Ø 3.75–5 mm), (3) the ridge width was at least 1.5 mm, (4) the alveolar ridge presented undercut that would lead to implant fenestration, (5) the prosthetically driven implant placement required implant placement in a given position on the arch where adequate bone dimensions were lacking, (6) esthetic considerations in the maxilla required an increase of the vestibulo-palatal dimensions.

Surgical procedure
In the maxilla
On the narrow ridge (Fig. 1a), a mid-crestal gingival incision was performed and a muco-periosteal flap of total thickness was raised (Fig. 1b). When relevant, mesial and distal soft tissue discharges were prepared to facilitate the visual access to the bone crest. Bone preparation of the sites included a mesial and distal discharge incision on the vestibular and the palatal sides as well as a longitudinal mid-crestal osteotomy (Fig. 1c). When a full arch or a hemi-arcade was treated, the discharge incisions were performed at the most distal site, at the canine and at the central incisor sites. Bone cutting was realized by continuous gentle upward–downward or forward–backward movements of the vibrating tip. The vertical mesial and distal discharge incisions were prepared 1 mm away from the teeth. In absence of teeth, the discharges were performed 3–5 mm away from the closest implant planned site. Subsequently, the longitudinal crestal incision was prepared and deepened down to 7–11 mm. The whole bone ostetomy procedure was performed with a single vibrating tip.

At the planned implant sites, osteotomes of 3–4 progressively larger diameters from 1 to 3.5 mm (3i, Palm Beach Gardens, FL, USA) were impacted (Fig. 1d). This mobilized and expanded gradually the vestibular bony flap, the implant bed was also created. Implants were then inserted flush with the bone level with a contra-angle at 15–20° until final seating (Fig. 1e), starting from the most distal implant to the most mesial one. After implant placement, the soft tissue was sutured and the implant was left to heal in a submerged way (Fig. 1f).
diameters (Bone management system, Meisinger, Neuss, Germany) were used. When bone was particularly dense, the crest was widened with a ridge expander (Fig. 2e). Implants were inserted starting from the distal site to the mesial one (Fig. 2f).

Use of platelet-rich plasma (PRP) and bone grafting material for bone coverage

When the initial alveolar ridge width was less than 3.5 mm, a PRP membrane (Marx et al. 1998; Petrungaro 2002; Marx 2004; Oyama et al. 2004) mixed with bone grafting material (Bio-Oss, Geistlich, Wolhusen, Switzerland) was seated over the implants and the oral and vestibular plates (Fig. 2g). The aim was to avoid a secondary resorption of the lateral cortical plates. For each 40 ml of blood, 15 ml of plasma were obtained; 0.5 g of Bio-Oss was mixed with 4 ml of plasma. The membrane was then activated with 0.5 ml of calcium gluconate and 0.5 ml of whole blood.

Demographics

Between January 2001 and May 2004, 79 split-crests procedures were performed in 57 patients to receive 230 implants. Fourteen (6.1%) implant sites were prepared with the PS, the other 216 (93.9%) implant sites were treated with the UBS. Patient age ranged between 23 and 82 years, mean age was 50.2 ± 13.9 years; 50.9% (29) were females and 49.1% (28) were males. In the maxilla, 152 implants (66.1%) were planned for placement; in the mandible they were 78 (33.9%). The majority of the sites (189, 82.2%) concerned the posterior region (Fig. 3). Indications were distributed into nine (11.4%) full arches, three (3.8%) hemi-arcades, 43 (54.4%) anterior or posterior partial bridges and 24 (30.4%) single crowns.

Alveolar ridge width and incision dimensions were measured with a periodontal probe at the nearest 0.5 mm. Initial width of the alveolar ridge varied from 1.5 to 5 mm, the average was 3.2 mm, 60.4% of the sites were ≤ 3 mm (Fig. 4). Final ridge width varied from 4 to 9 mm, average was 6 mm (Fig. 5). Split length varied from 5 to 40 mm, average was 15.1 mm, length distribution of the splits is given in Fig. 6. At sites where implants were placed, type I bone density was found at 26 (11.4%) sites, 60 (26.3%) sites were of type II, type III was found at 82 (36%) sites, type IV at 60 (26.3%) sites. Two implant types were placed; Osseotite implants (3i), Palm Beach Gardens, FL, USA with an external hex were 47 (20.6%), Leader implants (Milano, Italy) with an internal hex were 181 (79.4%). Implant diameter was distributed into 3.25 mm (1, 0.4%), 3.75 mm (188, 82.5%), 4 mm (6, 2.6%), 4.5 mm...
Fig. 2. Split-crest case in the mandible. (a) Clinical situation before surgery, (b) clinical situation after flap raising, (c) prepared incisions. Note the mesial and the crestal sections, (d) vestibular incision. In addition to the discharge incisions, a longitudinal basal discharge notch has been performed to mobilize easily the dense cortical table without breaking it, (e) crest widening with distractors. When the cortical table bone is dense, the bony flap is easily mobilized with 2 distractors, (f) placement of the implants. After crest widening with the distractors and site preparation with the osteotomes, the implants are placed. (g) Simultaneous bone grafting. When the residual cortical plates were thin, a platelet-rich plasma membrane with Bio-Oss was placed on the crest in order to avoid crestal bone loss around the implants.
and 5 mm (2, 0.9%) as shown in Table 1. Implant length was 8.5 mm (2, 0.9%), 10 mm (58, 25.4%), 11.5 mm (34, 14.9%), 12 mm (3, 1.3%) and 13 mm (131, 57.5%) as given in Table 1. One hundred and fifty-one (66.2%) sites were covered with PRP and bone grafting material, 77 (33.8%) were not. A healing period of 5–6 months was allotted in the mandible and in the maxilla. When implants were clinically stable at second surgery, the classical prosthetic steps were further undertaken.

**Results**

Of the 230 planned implants, two (0.9%) could not be placed because of fracture of the internal table in the maxilla at sites # 12 and 22. Of the 228 placed implants, eight (3.5%) implants failed to integrate at second stage surgery. All failures happened in the maxilla, seven in the anterior region and one in the premolar area. The initial ridge width of the failed implants was 2.5 mm (one implant), 3 mm (five implants) and 3.5 mm (two implants); split length was 7–8 mm for five implants and 10–20 mm for three implants. The failed implants were 10 mm long (one implant), 11.5 mm (three implants) and 13 mm (four implants). All other implants passed the second stage surgery and have been loaded for at least 2 months. The 3-year life-table analysis of loaded implants (Table 2) shows that 181 and 77 implants have been loaded for at least 6 and 12 months; 27 implants have passed 2 years and eight have been loaded for at least 30 months. Because no implant failed after loading, the cumulative survival rate of loaded implants was 100%.

With eight failed implants, the success rate of the placed implants at second-stage surgery was 96.5%. With 10 (two could not be placed, eight failed at second-stage surgery) planned implants that could not support a prosthesis, the success rate of the split-crest procedure with USBS was 95.6% at loading.

**Discussion**

The split-crest procedure in combination with immediate implant placement has been described more than 10 years ago (Simion et al. 1992; Scipioni et al. 1994). Case reports (Shimoyama et al. 2001; Coatoam & Mariotti 2003) and studies have been scarce (Scipioni et al. 1994; Sethi & Kaus 2000; Basa et al. 2004); survival rates in the 97–100% range have been reported. This procedure discards the
need for onlay grafts taken from the hip, the maxillary tuberosity, the symphysis of the chin or the external oblique ridge. It avoids the use of a secondary surgical site that exhibits postoperative morbidity associated with bone harvesting; the GBR technique is also avoided. An additional advantage of the procedure is that immediate implant placement shortens the treatment and reduces the costs.

Classical ridge-split procedures involve razor-sharp bone chisels, rotating or oscillating saws. Bone chisels are impacted into bone by a mallet with precise and gentle blows; the approach is time-consuming, it requires technical skills and a long learning curve. With rotating saws the procedure is more rapid but soft tissues like the tongue, the cheek or the lips can be encroached during preparation of the bone incisions; in addition, close access to adjacent teeth is rather difficult. Furthermore, with the aforementioned techniques, realization of the discharge vertical incisions requires more efforts and circumspection. With USBS, these limitations are no more relevant; the split-crest procedure is less technically sensitive and the learning curve of the technique is dramatically reduced. The risk of soft tissues injury is discarded and any shape of bone incision in the horizontal and the vertical direction can be easily performed without danger of altering any adjacent structure. In addition, the cavitation effect cleans the working area, visibility while working is increased. The vibrating tip can penetrate up to 12 mm in bone without risk of bone overheating at the condition to use gentle coming and going movements. In the mandible where bone is dense, mobilization of the vestibular flap is rather difficult; the use of a widening device increases the risk of bone fracture.

However, the basal longitudinal discharge notch described here, permits a safe and rapid mobilization of the vestibular cortical flap. Noteworthy, the latter can be only rarely performed with a rotating instrument because of the axis, the limited access in the vestibule and because of soft tissue proximity.

Increased power of the ultra-sonic vibrations enhances the bone cutting efficacy in hard bone. Less pressure on the working tip is requested; this alleviates the risk of thermal bone necrosis. In addition, high power is requested to treat soft bone of type IV; the softer the bone the higher is the power necessary to cut the bone. The additional power of the UBS permitted to treat 60 (26.3%) sites that were type IV bone.

The created furrow was not filled with a grafting material. This did not preclude filling and complete bone healing of the furrow as previously reported (Scipioni et al. 1999; Coatoam & Mariotti 2003). This is obtained because a stable space is delimited by the cortical plates and the latter is maintained over the healing period (Scipioni et al. 1999). Some authors (Coatoam & Mariotti 2003) observed an early saucerization of the crestal bone around implants that are placed flush with the crest of the ridge; this feature was also presently observed. To avoid the above-mentioned crestal bone loss, the treated ridges were covered with a PRP membrane associated with bone grafting material. However, efficacy of this procedure to achieve this goal still remains to be determined because measurements of the crestal bone level on radiographs at implant placement and at second-stage surgery were not performed.

![Fig. 5. Distribution of the final alveolar ridge width at implant site.](image1)

![Fig. 6. Distribution of the length of the longitudinal split-crest incisions. 113 splits have been performed to place 228 implants.](image2)

<p>| Table 2. Life-table analysis of loaded implants |</p>
<table>
<thead>
<tr>
<th>Loading interval (m)</th>
<th>Loaded implants at risk</th>
<th>Drop-out</th>
<th>Failures</th>
<th>Survival on interval (%)</th>
<th>Cumulative survival rate (%)</th>
</tr>
</thead>
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<tr>
<td>0–6</td>
<td>220</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
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<tr>
<td>6–12</td>
<td>181</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
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<td>12–18</td>
<td>77</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
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<tr>
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<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
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<tr>
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<td>100</td>
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<tr>
<td>30–36</td>
<td>8</td>
<td>0</td>
<td>0</td>
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<td>100</td>
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</table>

The table shows that no implant was lost after loading.
The split-crest technique with USBS was highly predictable, as 99.1% of the planned implants were successfully placed. The survival rate of the placed implants was 96.5%, comparable with results obtained with standard implant placement procedures [Esposito et al. 1998]. This proves that the USBS technique did not lead to bone overheating or injury that might be deleterious to bone repair. Changes in the split-crest procedure were implemented to adapt to the local bone conditions, such as the use of bone grafting material or not, use of PRP of not, or the use of distinct metallic devices in the mandible and in the maxilla to widen the space created between the cortical tables. However, they do not impact on evaluation of the present bone cutting technique. The fact that osteointegration was obtained despite these variations stresses the predictability of this novel osteotomy technique. One last noteworthy point is that all failures happened in the maxilla. When split according to the jaw, the survival rate in the mandible was 100% and 94.7% in the maxilla, in line with the trend observed for classical implant placement. In contrast to normal implant placement procedures, the posterior region was more successful than the anterior one, 99.5% vs. 82%.

Conclusion

Segmental ridge-split with USBS is predictable and does not lead to bone overheating or bone injury. This surgical technique is rendered safe, less technique sensitive, and comfortable, without risk of soft tissue encroaching. With 99.1% of the planned implants placed and a survival rate of 96.5% for the placed implants after 2 months of loading, this technique compares well to classical implant placement procedures. The USBS device had a better bone cutting efficiency, especially in softer bone because of a higher vibrating frequency range and increased power.

References


