

## CLINICAL STUDY

# The Modified Socket Shield Technique: A Prospective Clinical Study With 1 Year of Follow-Up

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**Objective:** In the anterior regions, the resorption of the buccal bone after tooth extraction leads to a contraction of the overlying soft tissues, resulting in an esthetic problem, particularly with immediate implant placement. In the socket shield technique, the buccal root section of the tooth is maintained, to preserve the buccal bone for immediate implant placement. The aim of this prospective study was to investigate the survival, stability, and complication rates of implants placed using a “modified” socket shield technique.

**Methods:** Over a 2-year period, all patients referred to a dental clinic for treatment with oral implants were considered for inclusion in this study. Inclusion criteria were healthy adult patients who presented nonrestorable single teeth with intact buccal periodontal tissues in the anterior regions of both jaws. Exclusion criteria were teeth with present/past periodontal disease, vertical root fractures on the buccal aspect, horizontal fractures below bone level, and external/internal resorptions. The buccal portion of the root was retained to prevent the resorption of the buccal bone; the shield was 1.5 mm thick with the most coronal portion at the bone crest level. All patients then underwent immediate implants. In the patient with a gap between the implant and shield, no graft material was placed. All implants were immediately restored with single crowns and followed for 1 year. The main outcomes were implant survival, stability, and complications.

**Results:** Thirty patients (15 males, 15 females; mean age was  $48.2 \pm 15.0$  years) were enrolled in the study and installed with 40 immediate implants. After 1 year, all implants were functioning, for a survival rate of 100%; excellent implant stability was reported (mean implant stability quotient at placement:  $72.9 \pm 5.9$ ; after 1 year:  $74.6 \pm 2.7$ ). No biologic complications were reported, and the incidence of prosthetic complications was low (2.5%).

**Conclusions:** The “modified” socket shield technique seems to be a successful procedure when combined with immediate implant placement, because the root fragment does not interfere with osseointegration and may be beneficial for the esthetics, protecting the buccal bone from resorption.

**Key Words:** Bone preservation, complications, immediate implants, socket shield, stability, survival

(*J Craniofac Surg* 2018;00: 00–00)

Nowadays, rehabilitation of esthetic areas with immediate postextractive single dental implants is a predictable procedure characterized by high survival rates in the short<sup>1,2</sup> and long terms.<sup>3,4</sup>

However, immediate insertion of postextractive single implants in areas of high esthetic value remains a challenge for the clinician because it is difficult to obtain a restoration that can mimic the emergencies and profiles of nature, in perfect symmetry with the natural, contralateral tooth.<sup>2,4</sup>

To achieve a successful esthetic outcome with a single implant-supported restoration in the anterior region, in fact, it is mandatory to preserve and maintain intact the bone anatomy, as well as the overlying soft tissues architecture.<sup>4–6</sup>

Unfortunately, as has long been known, tooth extraction causes alveolar bone resorption: this is a physiologic phenomenon, due to the fact that the periodontal ligament is lost with its vascular supply.<sup>7–9</sup> This bone resorption, which usually occurs within the first month after tooth extraction, causes a contraction or recession of the overlying soft tissues<sup>10,11</sup> that can be marked, especially in the anterior maxilla.<sup>9–11</sup> In fact, in the anterior maxilla, the delicate and thin buccal bone receives most of its vascular contribution from the periodontal ligament.<sup>10,12</sup>

Although bone resorption and soft tissue contraction do not represent an impediment for the placement of successfully osseointegrated implants, they can cause an esthetic problem for the clinician, because it can be difficult or impossible to fabricate a restoration that mimics the soft tissues’ architecture of the natural, contralateral tooth.<sup>2,4,6,9,10</sup>

Over the years, different surgical techniques have been proposed to counteract, or at least limit, the physiologic bone resorption that occurs after tooth extraction in the anterior areas of both jaws (and particularly in the high esthetic areas of the anterior maxilla). Among them are variants of alveolar socket preservation,<sup>13,14</sup> gingival grafts,<sup>15</sup> bone regeneration with membranes,<sup>16</sup> and/or grafting materials.<sup>17,18</sup>

Although all these techniques may, in different ways, limit or mask the unpleasant effects of bone resorption of the buccal bone wall (and the consequent contraction of the overlying soft tissues), allowing for successful esthetic rehabilitation in the anterior areas, none can completely eliminate the problem, which is inevitably linked and caused by the extraction of the tooth.<sup>8,10,19</sup>

An alternative to the conventional techniques can now be proposed—the so-called “socket shield” technique, which was first described by Hürzeler et al.<sup>20</sup>

This technique consists in the sectioning and removal of the crown of the compromised, nonrestorable tooth, leaving only the root, which is then sectioned into 2 parts, mesiodistally.<sup>20,21</sup> The palatal root portion is gently extracted, taking care not to damage or mobilize the buccal portion of the root.<sup>20,21</sup> The buccal portion of the root, in contact with the buccal bone, is left in situ after being reduced in thickness (to assume a concave shape similar to the

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Received November 6, 2017.

Accepted for publication February 1, 2018.

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The authors report no conflicts of interest.

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ISSN: 1049-2275

DOI: 10.1097/SCS.0000000000004494



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profile of the bone crest) and in height (up to 1 mm above the bone ridge).<sup>20,21</sup> Finally, an immediate implant is placed, palatally to the residual buccal root portion.<sup>20–22</sup>

This technique aims to preserve the periodontal ligament associated with the buccal portion of the root and its important vascular supply, which yields the possibility of avoiding the physiologic resorption of the buccal bone wall that is usually triggered by conventional tooth extraction.<sup>20–22</sup> The maintenance of the periodontal ligament and hence of the associated blood vessels can, in fact, prevent physiologic bone resorption of the buccal bone and therefore the contraction of the overlying soft tissues: this may contribute to better esthetic outcomes.<sup>20–22</sup>

The socket shield technique has specific indications: in fact, it is indicated for the anterior areas of both jaws (and particularly for the anterior maxilla), in the patient with teeth that cannot be restored due to traumas (crown fractures) or destructive caries.<sup>23</sup> Conversely, the socket shield technique cannot be applied to teeth with present (or past) periodontal disease, to teeth with mobility or widening of the periodontal ligament, to teeth with vertical root fractures or horizontal fractures below bone level, or to teeth with external/internal resorptions.<sup>23</sup>

In the last few years, different research groups have revisited the technique originally introduced by Hurzeler<sup>20</sup> and have proposed variants.<sup>24–28</sup>

Gluckman et al, who have renamed this technique partial extraction therapy, suggest that, if present, the gap between the implant and the buccal portion of the root should always be grafted with particulate grafting material.<sup>26,27</sup>

By contrast, Sirompas and Mitsias suggest that it is not necessary to graft the space between the residual buccal root portion and the implant<sup>24,25</sup>; moreover, because the essence of this method consists of preserving the periodontal ligament and hence the associated vascular contribution, they prefer to name this procedure “root membrane technique.”<sup>24,25</sup>

Although the socket shield technique is rapidly spreading among clinicians all over the world,<sup>23</sup> only a few clinical studies are available on this topic,<sup>22,24–28</sup> and therefore, little is known about the possible failures and/or complications associated with this method.

The aim of our present prospective clinical study was to examine the survival and complication rates of implants placed with a “modified” socket shield technique, in which the thickness of the shield was kept at 1.5 mm, the most coronal portion of the residual root was placed at the bone crest level (and not 1 mm above the bone crest), and no grafting material was inserted in the gap between the residual root and the implant.

## METHODS

### Inclusion and Exclusion Criteria

Over a 2-year period (January 2014–December 2015), all patients referred to a single private dental clinic (EasyPlant Dental Clinic, Gwangju, South Korea) for treatment with dental implants were considered for inclusion in this study.

Inclusion criteria were adult patients (age  $\geq 18$  years) with a noncontributory medical history (in good systemic and oral health) who presented one or more nonrecoverable (fractured or decayed) single hopeless teeth (with neighboring teeth on the mesial and distal) in the anterior regions (incisors-cuspids, premolars) of both arches, with intact buccal periodontal tissues as far as could be diagnosed preoperatively. Sufficient bone volume to allow placement of an implant at least 7 mm long and 3.5 mm in diameter and dentition in the opposing jaw were additional inclusion criteria, together with the ability to read and sign an informed consent form.

Exclusion criteria were a medical history that contraindicated oral surgical treatment (uncontrolled/untreated diabetes mellitus, immunocompromised status, radio/chemotherapy of the oral and maxillofacial region, treatment with oral and/or intravenous aminobisphosphonates, alcohol and/or drug abuse or psychic disorders), and teeth with present or past periodontal disease or widening of the periodontal ligament, teeth with vertical root fractures on the buccal aspect, teeth with horizontal fractures below bone level, and teeth with external or internal resorptions.

Conversely, periodontal biotype (thin, normal, or thick), smoking habit, presence of parafunctions (bruxism and/or clenching) and apical pathology did not represent exclusion criteria for the present study.

All patients were fully informed about the nature of this study and the planned treatment protocol, and all received information about possible alternative treatment options, including more conventional implant therapies (ie, tooth extraction followed by guided bone regeneration and implant placement with a delayed loading protocol). In addition, all patients received a thorough explanation of the potential risks and complications related to this clinical protocol, and all signed a written informed consent form prior to being enrolled in this study. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki on clinical research involving human subjects, 1975 (revised in 2008) and was approved by the local ethics committee.

### Preoperative Study

Prior to implant placement, each patient was investigated clinically and radiographically. Panoramic and periapical radiographs formed the basis of the primary investigation; cone-beam computed tomography (CBCT) scans were used as the final investigation, when necessary, to assess more accurately the bone volume available for implant placement. The CBCT datasets were acquired and subsequently transferred to specific implant navigation software (R2Gate; Megagen, South Korea) to perform a 3-dimensional reconstruction of the edentulous ridges. With this navigation software, it was possible to correctly assess the width of each implant site and the thickness and density of the cortical plates and cancellous bone, as well as the ridge angulations. The preoperative workup also included an assessment of the ridge anatomy using casts and diagnostic wax-up to provide the clinician with a better understanding of the patient's prosthetic needs.

### Implant Design and Surface Characterization

The implants used in this study (AnyRidge, Megagen, South Korea) were tapered, with a knife-edge thread design and a nanostructured, calcium-incorporated surface. The strong self-cutting threads (Knifethread) were designed to ensure high initial stability.<sup>29,30</sup> The nanostructured surface (Xpeed), resulting from a sandblasting procedure (resorbable blast media treatment), and the subsequent incorporation of calcium ions by means of a hydrothermal method were designed to accelerate the bone healing processes.<sup>31,32</sup> The implants had a 5-mm deep conical connection ( $10^\circ$ ) combined with an internal hexagon and were available in different lengths (7.0, 8.5, 10.0, 11.5, and 13.0 mm) and diameters (3.5, 4.0, 4.5, 5.0, and 5.5 mm).

### Surgical and Prosthetic Procedures

Following administration of local anesthesia and preoperative rinsing with 0.12% chlorhexidine, a small crestal flap was elevated around the hopeless tooth, or a gingival retractor was used for visibility. The crown of the hopeless tooth was decoronated with a chamfer diamond bur and a large-head round diamond bur under copious irrigation, until the remaining tooth structure (root) was

leveled at the bone crest level. The root was then sectioned along the long axis into buccal and palatal halves with a long shank fissure bur. The lingual root fragment was carefully retrieved using sharp instruments like a periosteal elevator or a periosteal elevator. Care was taken not to mobilize the buccal root fragment. The remaining buccal root fragment was then thinned and concaved slightly with a long shank fissure bur. Thickness of the buccal root fragment should be at least 1.5 mm to ensure resistance to fracture and resorption. Then, the coronal part of this shield was bevelled to make a lingual slope for a better emergence profile with a large-head round diamond bur. Finally, the socket shield was checked for immobility so the implant could be inserted palatally into the socket shield.

The implant placement procedure was initiated following the drilling sequence suggested by the implant manufacturer. The drilling was initiated by engaging the palatal wall so that the buccal root fragment remained intact. Care was taken not to cause unintentional dislodgment of the retained root following preparation of the implant bed. After implant bed preparation, a tapered implant (AnyRidge) was placed, with or without direct contact to the retained root fragment. The surgeon was free to choose the most appropriate implant lengths (7, 8.5, 10, 11.5, and 13.0 mm) and diameters (3.5, 4.0, 4.5, 5, and 5.5 mm), according to clinical indications. A speed of 15 rpm with a torque of 50 N/cm was set for insertion of the implant. If the machine-driven insertion was discontinued because of high insertion torque (IT), then the last threads were placed with a manual wrench. All implants were inserted slightly below the crestal bone level: apico-coronally, the implant platform was placed 2 mm apical to the bone crest. Mesiodistally, the implant was placed at the center of the mesio-distal width of the definitive restoration, leaving a minimum of 1.5 mm between the implant and root of the adjacent teeth. Labio-palatally, the implant was placed along the palatal wall of the extraction socket to enhance primary stability. The stability of all implants was first checked as the absolute absence of axial or rotational movement on removal of the implant driver without use of the stabilizing wrench, as well as by means of the IT.<sup>33</sup> Immediately thereafter, implant stability was measured by resonance frequency analysis (RFA) with a dedicated instrument (Mega ISQ, Megagen, South Korea).<sup>33</sup> This portable instrument emitted magnetic pulses to a small magnet screwed directly onto the implant with 5 N/cm; the magnet started to vibrate, and the probe listened to the tone and translated it into an implant stability quotient (ISQ) value.<sup>33</sup> Implant stability quotient values ranged from 1 (minimum stability) to 100 (maximum stability). For each implant, 4 measurements were made at different sites (mesial, distal, buccal, and palatal sites); the mean of all measurements was rounded to a whole number and regarded as the final ISQ of the implant.<sup>33</sup>

In all patients, even if there was a gap between the implant and shield, no bone grafting material was placed, as Tarnow and Chu<sup>34</sup> advised.

The prosthetic procedures were as previously described.<sup>30</sup> All implants were immediately restored with a screw-retained acrylic provisional restoration upon a temporary abutment. Pick-up impressions were taken immediately after surgery or the following day. Provisional fixed restorations (screw-retained single crowns, with a hole created in the direction of the long axis of the implant to fit the abutment and the prosthetic screw) were fabricated in acrylic resin and delivered within 72 hours of implant placement. These restorations were carefully contoured and polished and were accurately designed to mimic the original tooth form, sealing the socket, and maintaining clot formation subgingivally. The provisional restorations were screwed to the implants, and the occlusal holes were closed with Teflon flowable resin composite. A meticulous occlusal check was

performed using an articulating paper, and all provisional restorations on implants that had an IT < 45 N/cm were abundantly discharged from occlusion to ensure nonfunctional loading of the immediately placed implants.

Postsurgical instructions included antibiotics and analgesic medication based on each patient's medical history as well as a chlorhexidine 0.12% oral rinse. A soft diet was recommended for 4 weeks. The patients were asked to return at 1, 2, and 3 weeks for postoperative evaluations. Follow-up appointments were scheduled for 1, 2, 3, and 6 months. The final follow-up control was scheduled 1 year after implant placement.

The provisional restorations were finally replaced with definitive restorations (metal-ceramic or full ceramic crowns). All definitive restorations were carefully evaluated for proper occlusion, and protrusion and laterotrusion were assessed on the articulator and intraorally. Maintenance care was provided every 6 months. All patients were enrolled in a recall program.

## Outcome Measures

Patients were asked to attend a clinical and radiographic assessment of the implants, peri-implant soft tissues, and prosthetic restorations at 1 and 2 weeks, 1, 2, and 3 months, and 1 year after implant placement, respectively. This evaluation was performed by the same operator (C-HH) who placed the implants. Implant survival, implant stability, biological, and prosthetic complications were the main outcome measures of this study.

## Implant Survival

An implant was defined as "surviving" if it was still present and regularly in function 1 year after placement.<sup>35</sup> Conversely, in all patients in which an implant had to be removed, the fixture was defined as "failed."<sup>35</sup>

The causes for which an implant could be removed were

- failure to osseointegrate with clinical mobility, but without any clinical sign of infection;
- persistent/recurrent peri-implant infection (peri-implantitis) with pain, suppuration, and massive bone loss with subsequent implant loosening;
- severe and progressive marginal bone loss in absence of any sign of infection; and/or
- implant body fracture.

## Implant Stability

Insertion torque and RFA were the methods used to measure implant stability.<sup>33,35</sup> The IT measured the rotational stability of the implant, in newtons per centimeter (N/cm), whereas the RFA measured the axial stability of the implant, with the ISQ as the unit of measure.

The IT of each fixture was assessed at the time of implant placement with a surgical motor with 20:1 reduction and/or with a calibrated manual torque wrench, as previously reported. Briefly, an IT of 50 N/cm was set at placement of the implants; if the machine-driven insertion was discontinued because of high IT, then the last threads were placed with a manual wrench.

The RFA was used to measure the ISQ of each fixture at placement, and 1 and 2 weeks, 1, 2, and 3 months, and 1 year after placement, respectively. As previously reported, a dedicated instrument was used to measure ISQ. For each implant, ISQ values (scaled 1–100) were measured from the 4 sites (mesial, distal, buccal, and palatal sites).<sup>33</sup> The mean of all measurements was rounded to a whole number and regarded as the final ISQ of the fixture.<sup>33</sup>

## Complications

The complications reported in this study were biological or prosthetic. The biological complications were all complications affecting the implant, the shield, and the peri-implant hard and soft tissues, whereas the prosthetic complications were all complications affecting the prosthetic prefabricated implant components (mechanical complications) as well as the prosthetic components fabricated by the dental technician (technical complications).<sup>29,30,35,36</sup>

The biological complications were

- pain and/or discomfort, edema and/or swelling after surgery;
- abnormal reactions at the bone-implant interface;
- mobilization of the root fragment;
- resorption of the root fragment;
- peri-implant mucositis, defined as a reversible clinical condition in which an inflammation of the peri-implant soft tissues was present, with bleeding on probing and/or suppuration associated with a pocket depth  $\geq 4$  mm, but no radiographic evidence of bone loss<sup>35</sup>;
- peri-implantitis, defined as a nonreversible clinical condition in which an inflammation of the peri-implant hard and soft tissues was present, characterized by pocket depth  $\geq 4$  mm and bleeding on probing and/or pus secretion, associated with evidence of radiographic bone loss ( $>2.5$  mm)<sup>35</sup>; and/or
- peri-implant marginal bone loss  $>1.5$  mm, without any symptoms or signs of infection, evidenced during the first year after implant placement.

The prosthetic complications were

- abutment screw loosening;
- abutment fracture; and/or
- chipping/fracture of the ceramic restorations.

The first 2 complications were considered mechanical because they affected prefabricated prosthetic implant components, whereas the last one was considered technical in nature because it affected prosthetic components fabricated by the dental technician.<sup>36</sup>

## Statistical Evaluation

All data were collected by the same experienced operator who treated all patients and were added to a statistical datasheet. First, the distribution of patients and implants was studied by means of descriptive statistics. Absolute and relative frequency distributions (%) were calculated for qualitative variables, both at the patient-level (patient gender, age at surgery, presence of smoking habit, and/or parafunctions) and at the implant-level (implant location, position, length and diameter, distribution of the fixtures per IT, and ISQ at placement). The chi-squared test was used to calculate the differences in distribution between the groups, with the significance level set at 0.005. Then, means, standard deviations, medians, and confidence intervals (95% CIs) were calculated for quantitative variables (such as patient age, IT, and ISQ). Finally, the implant survival rate and the incidence of biological and prosthetic complications were calculated, at the patient-level and at the implant-level, after 1 year of functional loading. All computations were carried out with statistical analysis software.

## RESULTS

In total, 30 patients (15 males, 15 females) were selected for inclusion in the present study and received 40 implants (4 patients had multiple indications for implant therapy: 1 patient received 6 implants, 1 received 3 implants, and 3 patients received 2 implants,

TABLE 1. Patient Distribution

|                                 | No of Patients | P*    |
|---------------------------------|----------------|-------|
| Gender                          |                |       |
| Males                           | 15 (50%)       | 1.0   |
| Females                         | 15 (50%)       |       |
| Age at surgery, y               |                |       |
| 20–39                           | 10 (33.3%)     | 0.004 |
| 40–59                           | 14 (46.7%)     |       |
| 60–79                           | 5 (16.7%)      |       |
| $\geq 80$                       | 1 (3.3%)       |       |
| Smoke                           |                |       |
| Yes                             | 9 (30%)        | 0.028 |
| No                              | 21 (70%)       |       |
| Parafunctions/bruxism/clenching |                |       |
| Yes                             | 7 (23.3%)      | 0.003 |
| No                              | 23 (76.7%)     |       |
| Total                           | 30             | —     |

\*Chi-squared test.

respectively). The mean age of the enrolled patients was 48.2 ( $\pm 15.0$ ) years (median: 41, range 20–82, 95% CI 42.9–53.5). With regard to the patients' distribution and the patients' ages at surgery, 10 patients (33.3%) were aged between 20 and 39 years, 14 patients (46.7%) were aged between 40 and 59 years, 5 patients (16.7%) were aged between 60 and 79 years, and only 1 patient (3.3%) had an age  $\geq 80$  years. Considering this, a statistically significant difference ( $P=0.004$ ) was found in the distribution of patients by age at surgery because most of the patients were young or adults, with only a few patients with an age  $\geq 60$  years. Nine of the enrolled patients (30%) were smokers, while 21 patients (70%) had no smoking habit. Although the number of smokers enrolled was rather high, no statistically significant difference was found in the distribution of patients by smoking habit ( $P=0.028$ ). Finally, 7 of the enrolled patients (23.3%) had a history of parafunctions (bruxisms/clenching), and 23 patients (76.7%) had no history of parafunctions. Because only a few patients suffered from bruxism and clenching, a statistically significant difference was found in the distribution of patients by parafunctional habits ( $P=0.003$ ). All data related to patients' demographics are summarized in Table 1.

With regard to the location of the implants, most (34/40: 85%) were placed in the maxilla, with only 6 implants (15%) inserted in the mandible: accordingly, a statistically significant difference ( $P<0.0001$ ) was found in the distribution of the implants by location. With regard to the position of the implants, 12 (30%) were central incisors, 10 (25%) were lateral incisors, 5 (12.5%) were cuspids, and 13 (32.5%) were premolars. No statistically significant difference ( $P=0.283$ ) was reported in the distribution of the implants by position. Conversely, most of the implants inserted were 11.5 mm in length (85%), with only 3 implants (7.5%) with a length of 10.0 mm, 2 implants (5%) with a length of 13.0 mm, and 1 implant (2.5%) with a length of 7.0 mm. Accordingly, a statistically significant difference ( $P<0.0001$ ) was found in the distribution of the implants by length. A statistically significant difference ( $P=0.0017$ ) was found in the distribution of implants by diameter as well. In fact, the most frequently used implant diameters were 4.0 mm (16/40: 40%) and 4.5 mm (11/40: 27.5%), followed by 3.5 mm (8/40: 20%), 5.0 mm (4/40: 10%), and 5.5 mm (only 1 implant: 2.5%). Finally, no differences were found in the distribution of the implants by IT ( $P=0.751$ ), with 19 implants with an IT  $<45$  and 21 implants with an IT  $\geq 45$ .

**TABLE 2.** Implant Distribution

|                                         | No of Implants | P*      |
|-----------------------------------------|----------------|---------|
| Location                                |                |         |
| Maxilla                                 | 34 (85%)       | <0.0001 |
| Mandible                                | 6 (15%)        |         |
| Position                                |                |         |
| Central incisors                        | 12 (30%)       | 0.283   |
| Lateral incisors                        | 10 (25%)       |         |
| Cuspids                                 | 5 (12.5%)      |         |
| Premolars                               | 13 (32.5%)     |         |
| Length, mm                              |                |         |
| 7.0                                     | 1 (2.5%)       | <0.0001 |
| 10.0                                    | 3 (7.5%)       |         |
| 11.5                                    | 34 (85%)       |         |
| 13.0                                    | 2 (5%)         |         |
| Diameter, mm                            |                |         |
| 3.5                                     | 8 (20%)        | 0.0017  |
| 4.0                                     | 16 (40%)       |         |
| 4.5                                     | 11 (27.5%)     |         |
| 5.0                                     | 4 (10%)        |         |
| 5.5                                     | 1 (2.5%)       |         |
| Insertion torque                        |                |         |
| <45                                     | 19 (47.5%)     | 0.751   |
| ≥45                                     | 21 (52.5%)     |         |
| Implant stability quotient at placement |                |         |
| <65                                     | 2 (5%)         | <0.0001 |
| 65–75                                   | 26 (65%)       |         |
| >75                                     | 12 (30%)       |         |
| Total                                   | 40             | —       |

\*Chi-squared test.

Conversely, a statistically significant difference ( $P < 0.0001$ ) was found in the distribution of the implants with regard to the ISQ at placement. In fact, most of the implants (26/40: 65%) had an ISQ value between 65 and 75 at placement, with 12 implants (12/40: 30%) with an ISQ  $> 75$  and only 2 implants (2/40: 5%) with an ISQ at placement  $< 65$ . All data related to implant distribution are summarized in Table 2.

At the end of the study, 1 year after implant placement, all fixtures were in function, for an overall survival rate of 100%, both at the patient and at the implant-level.

At placement, a mean IT of 39.9 ( $\pm 16.3$ , median 45, 95% CI 34.6–44.6) was reported, whereas a mean ISQ of 72.9 ( $\pm 5.9$ ,

**TABLE 3.** Implant Stability

|                  | No of Implants* | Mean | SD   | Median | 95% CI    |
|------------------|-----------------|------|------|--------|-----------|
| IT               | 40              | 39.6 | 16.3 | 45     | 34.6–44.6 |
| ISQ at placement | 40              | 72.9 | 5.9  | 73.5   | 71.1–74.7 |
| ISQ 1 wk         | 19              | 76.2 | 3.2  | 75     | 74.8–75.6 |
| ISQ 2 wk         | 7               | 73.3 | 2.0  | 74     | 71.9–74.7 |
| ISQ 1 mo         | 12              | 71.7 | 4.3  | 75     | 69.3–74.1 |
| ISQ 2 mo         | 10              | 73.1 | 3.4  | 72     | 71.0–75.3 |
| ISQ 3 mo         | 7               | 74.4 | 5.1  | 76     | 70.7–78.0 |
| ISQ 1 y          | 40              | 74.6 | 2.7  | 75     | 73.8–75.4 |

CI, confidence interval; ISQ, implant stability quotient; IT, insertion torque; SD, standard deviation.

\*No of the effectively measured implants (not all patients attended all the interim follow-up control visits).

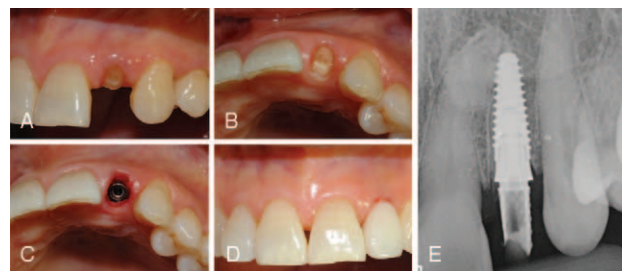


**FIGURE 1.** A 65-year-old female patient requested replacement of the left lateral incisor (No 22) due to a horizontal fracture: (A) preoperative situation, frontal view; (B) preoperative situation, occlusal view; (C) the root was sectioned and the lingual fragment was carefully removed. The remaining buccal fragment was thinned and concaved. After implant bed preparation, a tapered implant (AnyRidge) was inserted in contact with the retained root fragment; (D) a screw-retained provisional crown was fabricated and tightened onto the implant with 25 N/cm, the day after surgery; (E) postoperative periapical radiograph.

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median 73.5, 95% CI 71.1–74.7) was found. Finally, 1 year after implant placement, a mean ISQ of 74.6 ( $\pm 2.7$ , median 75, 95% CI 73.8–75.4) was registered. All data related to implant stability, including information obtained at the interim follow-up control visits (1, 2 weeks and 1, 2, 3 months after implant placement, respectively), are summarized in Table 3.

Finally, with regard to complications, no biologic complications (0.0%) were reported in the present study. However, 1 abutment became loose 2 months after insertion: this was considered a mechanical complication, minor in nature because the abutment was reinserted, screwed again, and no further prosthetic complications occurred during this study. No technical complications were registered. The incidence of prosthetic complications was therefore of 3.3% (patient-level, 1/30 patients) and of 2.5% (implant-level, 1/40 implants) (Figs. 1–4).

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## DISCUSSION

One of the greatest difficulties and pitfalls in inserting single postextracting implants in esthetic areas, especially in the anterior maxilla, is bone resorption triggered by the tooth extraction.<sup>2–6</sup> Tooth extraction results in loss of the periodontal ligament, which with its vascular supply carries nutrition to the buccal bone plate.<sup>7–11</sup> In the absence of this nourishment, the buccal bone plate undergoes physiologic resorption that mainly occurs within the first 4 to 6 months after tooth extraction.<sup>7–11</sup> This bone resorption inevitably follows a contraction of the overlying soft tissues, which causes for the patient, and therefore for the clinician, an esthetic problem.<sup>2–5,7,10,12</sup>

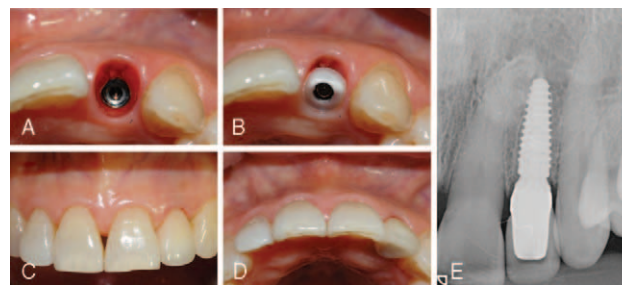


**FIGURE 2.** One week after surgery, the provisional restoration was removed (A) and the final impression was made. The definitive restoration consisted of a full zirconia abutment, tightened onto the implant using 30 N/cm of torque (B) and a full lithium disilicate crown (C, D), which was delivered after 2 weeks. A periapical radiograph was taken at the delivery of the final restoration (E).



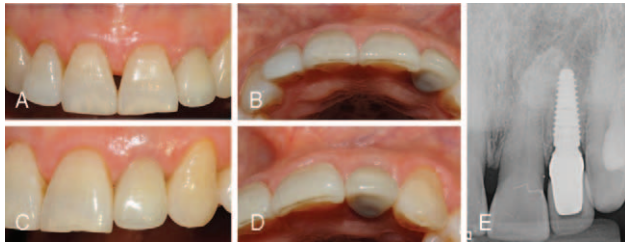


**FIGURE 3.** After 1 year of functional loading, the gingival architecture around the implant was well preserved, as evidenced from different views (A–D). The 1-year radiographic evaluation confirmed the stability of bone tissue around the implant (E).

Various strategies have been proposed to limit this physiologic resorption and therefore provide the patient with a better esthetic result: among them are socket preservation,<sup>13,14</sup> gingival grafts,<sup>15</sup> guided bone regeneration with membranes,<sup>16</sup> and/or grafting materials.<sup>17,18</sup>

A possible alternative strategy for preserving the buccal bone in the anterior maxilla, avoiding its resorption and the related contraction of the overlying soft tissues, may be the maintenance in situ of the buccal portion of the root of the tooth that must be extracted.<sup>20</sup>

For some time, it has been known that root maintenance (also known as “root submerged technique”) can protect the alveolar bone from resorption.<sup>37–39</sup> Maintenance of the periodontal ligament and hence of the associated vessels may, in fact, prevent the physiologic bone resorption of the buccal bone, as has been demonstrated.<sup>37–39</sup> Root submerged technique can be successfully used in the edentulous areas of the bridges.<sup>40</sup>

In recent years, this method, named the “socket shield technique,” has been proposed in association with the placement of postextraction implants in esthetic areas, to eliminate the negative consequences of bone resorption of the buccal bone plate occurring after tooth extraction, and to obtain perfect esthetic outcomes.<sup>20,23</sup>

Although the socket shield technique is rapidly gaining popularity all over the world,<sup>23</sup> to date, only a few clinical and radiographic studies have reported on this surgical method.<sup>20,22,24–28,41,42</sup> Moreover, most of these are case reports,<sup>20,22,25,41,42</sup> case series,<sup>26,27</sup> or retrospective studies.<sup>24,28</sup>

In 2014, Siommpas et al<sup>24</sup> published a retrospective clinical study that evaluated immediate implant placement with simultaneous intentional retention of the buccal aspect of the root. The authors reported longitudinal data on survival of implants placed in the

anterior maxilla with the “root membrane technique,” as well as the complications that occurred with this procedure, up to 5 years postloading.<sup>24</sup> In total, 46 patients were evaluated (each patient received 1 single implant).<sup>24</sup> At the end of the follow-up period, all implants were in function for a 100% survival rate.<sup>24</sup> Radiographic examination revealed good crestal bone stability, with mean crestal bone loss on the mesial and distal aspects of the fixtures of 0.18 mm ( $\pm 0.09$ ) and 0.21 mm ( $\pm 0.09$ ), respectively.<sup>24</sup> The only complication was the apical root resorption of a single retained root fragment; however, this complication did not interfere with the osseointegration of the implant.<sup>24</sup>

In a retrospective clinical and radiographic study with 5 years of follow-up, Baumer et al<sup>28</sup> evaluated the safety of the socket shield technique, investigating the incidence of biological and implant-related complications and reporting on the esthetic outcomes, the conditions of the peri-implant soft tissues, and the volumetric changes of the facial contours. Ten patients with implant replacement in the anterior maxilla were enrolled in this study.<sup>28</sup> Impressions were taken prior to tooth extraction and 5 years postimplant placement, and the casts were scanned and digitally superimposed for a qualitative and quantitative evaluation of the alterations of the facial peri-implant tissue contours.<sup>28</sup> Moreover, clinical and radiographic data of each patient were collected at the 5-year follow-up control.<sup>28</sup> Five years after implant placement, all fixtures were in function, and the peri-implant tissues showed healthy conditions; physiologic bone remodeling was evidenced at the implant shoulders, with a mean bone loss of 0.33 mm ( $\pm 0.43$ ) and 0.17 mm ( $\pm 0.36$ ) at the mesial and distal aspect of the fixtures, respectively.<sup>28</sup> Mean tissue loss on the facial side in oro-facial direction was 0.21 mm ( $\pm 0.18$ ), and the average recession at fixtures and at neighboring teeth was 0.33 mm ( $\pm 0.23$ ) and 0.38 mm ( $\pm 0.27$ ), respectively, with a mean pink esthetic score of 12.<sup>28</sup> The authors concluded that a low degree of contour changes from extraction and implant placement to the 5-year follow-up was evidenced, with recession at the implants that was comparable to those of the neighboring teeth.<sup>28</sup>

In our prospective clinical study, we have reported on the clinical and radiographic results obtained with a “modified” socket shield technique after 1 year of implant placement. In total, 30 patients were selected for inclusion in the present study and received 40 implants (4 patients, in fact, had multiple indications for implant therapy). Implant survival, implant stability, biologic, and prosthetic complications were the main outcomes of the study.

At placement, a mean IT of 39.9 ( $\pm 16.3$ , median 45, 95% CI 34.6–44.6) and a mean ISQ of 72.9 ( $\pm 5.9$ , median 73.5, 95% CI 71.1–74.7) were registered, respectively. All implants were immediately restored with a provisional acrylic resin crown. Although the ISQ values registered at placement were rather high, only 19/40 implants (47.5%) had an IT  $\geq 45$  N/cm. Therefore, according to our established and previously reported loading protocol,<sup>30</sup> all provisional restorations supported by implants that had an IT  $< 45$  N/cm were abundantly discharged from occlusion to ensure nonfunctional loading of the immediately positioned fixtures. Over the course of the months, the recorded ISQ values showed a positive progression, going to stabilize upward. One year after implant placement, a mean ISQ of 74.6 ( $\pm 2.7$ , median 75, 95% CI 73.8–75.4) was registered. As previously reported,<sup>29,33</sup> in fact, the macrotopographical features of the tapered implants used here, characterized by knife-edge threads, can provide excellent implant stability, with no decrease or drop in the stability values (ISQ) over time. The body of this fixture is narrower than the threads, and the threads are aggressive: this shape may provide better anchorage to bone and guarantee a high stability during the healing period, with no drops in the ISQ values.<sup>33</sup>

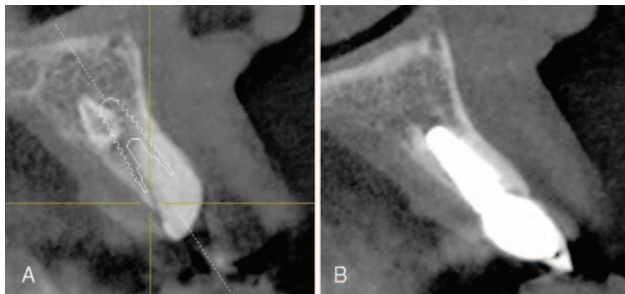


**FIGURE 4.** Preoperative (A) and 1-year follow-up control (B) CBCT. In the follow-up CBCT scan, shield is hardly distinguished from buccal bone plate. Periodontal ligament between shield and bone plate underwent atrophy. And even though fractured tooth did not have an endodontic treatment, shield and bone plate were well fused and look like cortical bone (corticalization). The implant was in contact with the shield. CBCT, cone-beam computed tomography.

At the end of the study, 1 year after implant placement, all fixtures were in function, for an overall survival rate of 100%; no biologic complications were reported, whereas 1 patient (1 implant) experienced a minor prosthetic (mechanical) complication.

The surgical technique described in our study has 3 important differences from the classically method described by Hurzeler et al.<sup>20</sup>

First, the shield is reduced to a thickness of 1.5 mm, with a concave profile. Second, the most coronal part of the root is left at the bone crest level (and not 1 mm above, as described by Hurzeler et al.).<sup>20</sup> Third, no graft material is placed in the space between the shield and the implant, in accordance with Siormpas<sup>24</sup> and Mitsias,<sup>25</sup> but in contrast with Gluckman et al.,<sup>26,27</sup> who suggest grafting this space with particulate material. According to Tarnow and Chu, in fact, the immediate placement of implants into extraction sockets with an intact buccal wall allows healing and osseointegration despite a large gap distance and without primary flap closure, a bone graft or a barrier membrane.<sup>34</sup>

Although the clinical results obtained through the socket shield technique can be considered encouraging, as confirmed in our present prospective clinical study, it is important to note that at present, there is only 1 human histologic study in the current literature that support the goodness of this technique.<sup>43</sup> In this paper, the authors presented histologic evidence of an immediate implant placed in the human anterior maxilla, according to the socket shield technique, and retrieved after 5 years.<sup>43</sup> The specimen was processed for histologic/histomorphometric evaluation, and the authors demonstrated that the buccal bone plate was maintained without any resorption, with a healthy periodontal ligament preserved. The implant showed osseointegration, with a high percentage of bone-to-implant contact (76.2%).<sup>43</sup> With regard to the space between the root and the implant, the apical and medial thirds were filled with compact, mature bone, whereas the coronal third was colonized by noninfiltrated connective tissue.<sup>43</sup> The authors concluded that the socket shield technique was effective in preventing bone resorption of the buccal bone plate of the human anterior maxilla, 5 years after the placement of an immediate implant.<sup>43</sup> All other available histologic studies on the socket shield technique are animal studies,<sup>21,44</sup> and only one of these experimental studies is supported by an adequate number of histologic samples.<sup>44</sup>

Our present study has limits: in fact, patients were followed for only 1 year after implant placement. It is certainly necessary to have a longer follow-up period to be able to draw more specific conclusions on the reliability of this “modified” socket shield technique. Therefore, it will be necessary to follow this cohort of patients for a longer period of time to investigate the occurrence of any potential complication affecting the socket shield and the implants in the long term. In addition, in this study, we only evaluated clinical and radiographic outcomes, but we did not make a 3-dimensional volumetric analysis of tissue stability. A volumetric analysis through the use of modern digital technologies and software dedicated to 3-dimensional image superimposition would allow us to evaluate the stability of hard tissues (buccal bone, through the overlapping of pre- and post-operative CBCT)<sup>9</sup> and soft tissues (through the overlapping of 2 intraoral scans: the preoperative scan and different postoperative scans).<sup>45–47</sup> Only in this way, and with the important confirmation given by a human histologic study, we will be able to draw more specific conclusions about the treatment procedure presented in this study.

## CONCLUSIONS

Within the limits of the present study (limited follow-up time and absence of a throughout volumetric analysis), the modified socket shield technique described here seems to be a safe and successful

treatment procedure, with high implant survival rates (100% implant survival 1 year after placement) and low complication rates (no biologic complications encountered). Further long-term follow-up studies are needed to confirm these results.

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