

## CASE STUDY

# Soft and hard tissue evaluation of guided socket shield implant cases

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**Abstract**

**Background:** The socket-shield (SS) technique results in long-term functional osseous- and dento-integration, preserving the dimensional stability of hard and soft tissues over time. This study aimed to describe the successful implementation of a surgical technique to facilitate “SS” cases.

**Methods:** The cases included males and females aged 32–81 years consecutively treated between 2020 and 2023 (longest follow-up, 3.5 years). For each case, pre- and post-operative cone-beam computed tomography (Digital Imaging and Communications in Medicine files) and intraoral optical scans (IOS; STL files) were performed. Digital immediate implant placement and simultaneous tooth extraction and SS production were planned using an implant planning software. Implants were planned considering sagittal-ridge and tooth-root angular-configuration. Surgical guides were used to perform the digitally-supported SS technique. All cases were planned and surgically performed by one operator (Pedro M. Trejo). Preoperative digital IOS-models were superimposed to post-operative models to assess soft-tissue changes. Pre and post sagittal views were used to assess the radiographic buccal-plate thickness at various healing times. An investigator not involved with case planning or treatment performed measurements.

**Results:** Results reflected soft-tissue stability with minimal mean thickness change at 0-, 1-, 2-, and 3-mm measurement levels of 0.03, -0.2, 0.14, -0.07, and 0.04 mm, respectively, with a mean gingival-margin change of 0.04 mm. The free gingival-margin change ranged from a 0.58-mm gain in height to a -0.57-mm loss. The mean radiographic buccal-plate thickness post-operatively was 2.04 mm (range, 0.7–2.9 mm).

**Conclusion:** The digitally-supported guided SS technique enables predictable immediate implant-placement positions and stable buccal peri-implant soft and hard tissues over time.

**KEYWORDS**

computer-assisted, dental implantation, endosseous, socket-shield technique, surgery

**Key Points****Why are these cases new information?**

- The uniqueness of the surgical technique described herein is that it results in favorable positions of immediate, socket-shielded (SSed), implant placements, with soft- and hard-tissue stability as the byproduct.

**What are the keys to successful management of these cases?**

- Digitally, plan for the best possible implant position within the alveolar housing to satisfy prosthetic requirements, and then adjust this position to accommodate the socket shield dimensions.

- Digitally, provide a space/gap between the future dentinal shield and the implant.
- Clinically, allow for time to carve the final position and dimensions of the shield. Plan ahead the extent of the apical third of the SS, and the removal of the apex, if dealing with a long root.

#### **What are the primary limitations to success in these cases?**

- Inadequate use of digital technology; case-sensitive technique requires proper execution of each digital and technical clinical step.

## INTRODUCTION

Numerous studies, over the past decade, have reported that the “Socket-Shield” (SS) technique results in the maintenance of the buccal plate by avoiding its resorption after tooth extraction.<sup>1–4</sup> This partial extraction technique preserves the dimensional stability of the bone and corresponding soft tissues in the long term.<sup>2,5</sup> Biologically, the presence of a “shield”, consisting of a periodontal ligament, a thin buccal plate of bone, and a dentinal shield facing the implant surface, results in osseointegration. Assuming a sub-crestal implant and SS position, the healing outcome above the bone crest, results in connective tissue and junctional epithelium around the prosthetic abutment and the SS integrating well within the tissues; previously referred to as dento-integration.<sup>5</sup>

This technique was originally described by Hürzeler et al.<sup>1</sup> and has been modified by several other authors.<sup>6–9</sup> To achieve the desired biological and clinical outcomes, precise production of a dentinal shield is shaped during the partial tooth extraction procedure. In addition, an implant must be placed in a prosthetically favorable position after the extraction of the remaining palatal root. Consequently, shaping and preserving a thin buccal shield of dentin, extracting the remaining tooth, and placing an implant in a prosthetically accurate position, is time-consuming and technically demanding.

This clinical report aimed to describe a CAD-CAM protocol, and surgical guides derived from digitally planned implants, to facilitate the SS technique. In addition, the soft tissue positional and dimensional alterations of seven consecutively placed socket-shielded implants using the surgically guided implant placement and guided partial extraction technique are reported.

## MATERIALS AND METHODS

All patients were referred for evaluation and implant treatment of hopeless, non-restorable teeth in the esthetic zone. The cases involved healthy males and females with the age range of 32–81 years. They were consecutively treated between February 2020 and April 2023. The longest follow-up period was 42 months/3.5 years and the shortest was 5

months (Table 1). The following criteria were used to indicate the partial extraction therapy for these patients/teeth: 1. Single rooted non-restorable teeth, 2. presence of an intact buccal plate, 3. single-rooted teeth, 4. tooth mobility up to Miller Class I, 5. intact crestal bone levels of adjacent teeth, 6. absence of periodontal defects, 7. manageable periapical chronic infections, and 8. supra-crestal horizontal tooth fractures. Contraindications included: 1. mid-facial vertical or sub-crestal horizontal fractures, 2. soft tissue deficiencies that would necessitate pre- or post-soft tissue correction, 3. tobacco smokers, 4. un-controlled diabetics, acute infections at the surgical site; and 5. periodontal disease. Aesthetic demands were different for all patients. The surgical and prosthetic plan was explained, and verbal and written informed consent was obtained.

The pre-operative preparation for each patient comprised the following: data acquisition to digital treatment plan of the cases. Cone beam computed tomography (CBCT)<sup>\*</sup> was performed, with image acquisition parameters of 200 µm voxel, 90 kVp, 10 mAs, exposure time of 12.5 s, slice thickness of 0.5 mm, and field of view of Ø61×78 mm. The data from the CBCT, and Digital Imaging and Communications in Medicine (DICOM) files were imported into an implant planning software<sup>†</sup>. In addition, an intraoral optical scanner (IOS)<sup>‡</sup> was utilized to scan both maxillary and mandibular arches, record the inter-occlusal relationship and generate digital models. These models were saved as STL files, pre-socket-shield model files (pre-SS-m), and imported into the implant planning software. The DICOM and STL files were then merged using the software. A virtual wax-up representing the implant-supported crown was generated. Subsequently, the implant was planned in a favorable prosthetic position considering the sagittal ridge and root angular configuration of the tooth.

The implants were placed digitally within the bone housing, at or below the buccal bone crest, and in an angled position as needed using virtual screw-channel abutments for screw-retained restorations.

The three-dimensional position of the implants was digitally placed according to accepted guidelines and as described previously.<sup>10</sup> Figure 1A–F presents the digital

\* I-CAT Gendex GXCB-500 HD, Imaging Sciences International LLC, Hatfield, PA

† DTX Studio Implant, Envista Holdings Corporation, Brea, California USA

‡ Trios 3 Wired, 3Shape A/S, Copenhagen, Denmark

**TABLE 1** Gingival thickness change from the pre- and post-op socket shield (SS) models in a horizontal direction at 0, 1, 2, and 3 mm measurement levels, change in height of the free gingival margin, and pre- and post-operative radiographic buccal plate thickness, by case<sup>a</sup>.

Pt	Th type	Ø/length	Mths	0 mm	Thickness change ThΔ			GM Change LΔ	Xr-BP-Th/Xr-SS-Th
					1 mm	2 mm	3 mm		
1	11	4.3/13	15	1.50	0.27	0.10	0.02	0.26	0.9/2.8
2	11	4.3/16	10	-1.06	-0.66	-0.07	0.15	0.28	0.7/2.9
3	8	4.3/11.5	15	0	-0.51	-0.60	-0.49	-0.54	0.6/0.7
4	11	4.3/13	17	-0.56	-0.71	-0.37	-0.27	-0.57	0.9/2.3
5	8	4.3/13	15	0.99	0.72	0.65	0.50	0.58	0.8/1.7
6	9	4.3/13	5	-0.48	-0.61	-0.53	-0.33	0.19	0.9/2.1
7	10	4.3/16	42	-0.16	-0.36	-0.19	-0.11	0.11	0.7/1.9
Mean±SD				0.03 ± 0.83	-0.2 ± 0.54	0.14 ± 0.42	-0.07 ± 0.33	0.04 ± 0.43	0.78 ± 0.11/2.04 ± 0.6

<sup>a</sup>A negative measurement represents depletion, and a positive one, an increase in tissue thickness or gingival margin height.

Abbreviations: GM, gingival margin; Mths, months; Pt, patient; SD, standard deviation; Th, Tooth; Xr-BPTh, radiographic buccal plate thickness; Xr-SSTh, radiographic socket-shield thickness.

planning of the guided SS procedure and clinical outcomes. Figure 2A,B presents the digitally pre-planned SS and the resulting radiographic post-operative SS.

Once the implants were determined surgically and prosthetically adequate on the computer screen, a surgical guide was produced automatically by the implant software. Subsequently, the STL surgical guide file was imported into and prepared for printing using the dental 3D printer<sup>5</sup> utilizing the specified surgical resin, surgical Guide Resin 1 L. The printing, cleaning, and curing protocol was completed in-house as recommended by the manufacturer. The placement of the corresponding surgical sleeves was performed by the same laboratory technician. The guides were considered finished, once checked, polished, cleaned, and cold sterilized.

All patients were pre-medicated with antibiotics starting the day before the surgical procedures and continued for 7 days—post-operative medications included analgesics, and chlorhexidine rinse bid. All cases were planned and surgically performed by the same operator (Pedro M. Trejo). The guided SS procedural surgical steps were the same for all patients and are depicted in Figure 3A–M.

The tooth presented a horizontal fracture exposing the pulp of tooth # 9 (Figure 3A,B). The implant type, diameter, and length planned for this case were for a tapered implant<sup>II</sup> 4.3 × 13 mm, conical connection (Figure 3C–M). The surgical guided was precisely seated by reducing the coronal aspect of the tooth and adjusting the intaglio aspect of the guide as necessary.

1. The initial drilling through the tooth was performed at a speed of 1200–1400 rpm. With the surgical guide seated after removal of the fractured crown, using their corresponding drill guides, a 2-mm and then a 3.25-mm drill were used to simultaneously initiate both the implant osteotomy and the tooth extraction.

- As the implant osteotomy was being prepared, the buccal aspect of the tooth dentin reduced itself producing a thick buccal shield of dentin (SS) (Figure 3C–F).
- Mesial and distal vertical cuts were made to hemection the tooth before extracting the palatal root as atraumatic as possible (Figure 3G,H,I).
- Surgical drills specifically designed to produce an SS were then used.<sup>¶</sup> Careful sweeping motions, going mesial to distal, up and down, and back and forth with the drills, until a shield of approximately 1.5 mm width and 7–8 mm length is carved. The apex was removed and the SS immobility was confirmed, as previously recommended.<sup>8</sup>
- Lastly, the final 4.3-mm implant drill was used at a speed of 800 rpm before the implant placement. (Figure 3K).
- The final clinical outcomes are depicted in Figure 3L,M. Grafting of the residual gaps was completed with xenograft small granules (0.25–1 mm)<sup>#</sup> embedded with a growth factor<sup>\*\*</sup>.

The representative case measurements are not included in the data shown. The 6-month follow-up examination for this patient denoted the presence of a radiographic socket shield without any complications and with apparent soft tissue stability.

All implants were clinically stable at placement. A healing abutment or a full provisional crown, if indicated, was delivered at the end of the procedures. All patients were followed up post-operatively at 1–2 weeks and 1, 2, and 3 months to reinforce oral hygiene instructions and plaque control. The implant diameter and length for each case are summarized in Table 1.

Post-operative CBCT and intraoral scans were made at different time points after healing for each case (Table 1). Post-therapy digital models (post-SS-m) for each patient were generated and saved as STL files.

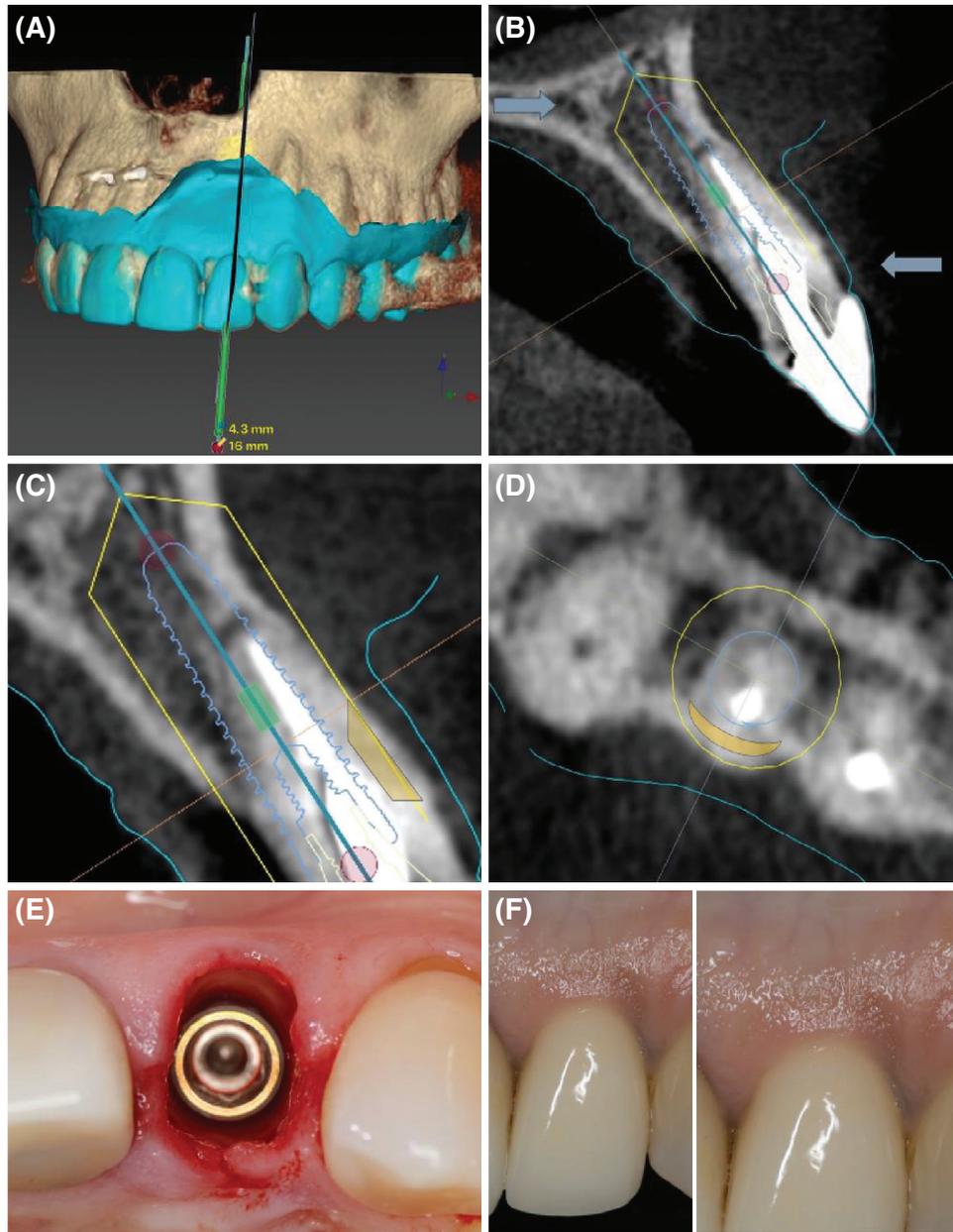
<sup>5</sup> Formlabs Form 3B+, Formlabs Inc., MA, USA

<sup>II</sup> Nobel Biocare, NobelReplace Tapered Implant, Brea, CA, USA

<sup>¶</sup> MegaGen America, Partial Extraction Kit, Fairlawn, NJ, USA

<sup>#</sup> Geistlich Pharma, North America Inc. Princeton, NJ, USA

<sup>\*\*</sup> GEM 21S Growth-factor Enhanced Matrix, Franklin, TN, USA



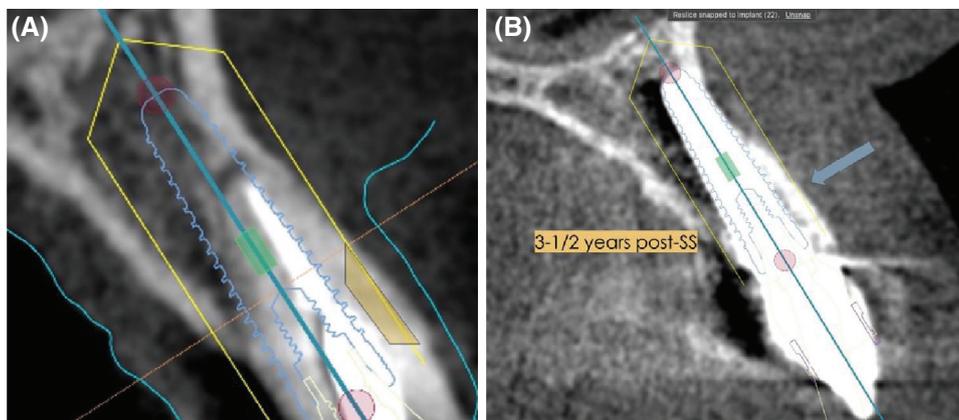
**FIGURE 1** Three-dimensional view of SS-model 1 after fusion with the CBCT/DICOM data. (A) Sagittal view of the tooth root and implant within the alveolar housing. (B) The digitally planned immediate implant and feasible SS. (C) SS buccal and (D) occlusal view. (E) Guided implant position in relation to the SS. (F) Soft tissue appearance 3.5 years post therapy. CBCT, Cone-beam computed tomography; DICOM, Digital Imaging and Communications in Medicine; SS, socket shield.

The obtained STL files were imported into a reverse engineering software program<sup>††</sup>. STL files from pre- and post-SS models were superimposed by manually adjusting for optimal alignment of repeatable anatomical landmark sites to assess volumetric mucosal alterations at treated sites following SS. The region of interest was the cervical third of the implant, 5 × 8 mm starting just above the free gingival margin. All measurements were conducted by a calibrated examiner (Arisa Nishikawa), and to ensure accuracy, 10% of the sites underwent random selection for repeated mea-

surements, with the second measurement differing by less than 5% from the first. The assessment included the following mucosal dimensional changes: 1) mucosal thickness change measured at the mid-facial aspect of each tooth at different locations: 0, 1, 2, and 3 mm relative and below the pre-operative gingival margin in mm (ThΔ); and 2) linear changes of the mucosal margin location (mm) (LΔ) (Figure 4A-C and Table 1).

Post-operative CBCT were generated and saved as DICOM files and imported into the implant planning software. The radiographic SS plate thickness (Xr-SS-Th) was measured after placing and superimposing a dig-

<sup>††</sup> Geomagic Control X 2023.3.0, Gent, Belgium



**FIGURE 2** CBCT cross-sectional pre- and post-operative views of (A) digitally planned SS and immediate implant, and (B) post-guided SS (42 months). Note the digitally placed implant on the post-operative view, and the resulting buccal “shield” (blue arrow). CBCT, Cone-beam computed tomography; SS, socket shield.

ital implant of the same dimensions over the actual implant shown on the post-operative CBCT. The resulting radiographic dentinal shield including the periodontal ligament and buccal plate thickness was measured on the sagittal view after centering the cross-sectional radiographic slice along the long axis of the implant, by using the “snap to implant” feature of the implant software.

One measurement per implant was made. Perpendicular to the long axis of the implant, using the measurement tool of the software, the thickness of the SS was measured from the most coronal level of the implant platform to the outer aspect of the buccal plate, (Figure 5A,B and Table 1). The pre-operative buccal plate thickness relative to the virtual implant position for each case was assessed and is depicted in Table 1.

## RESULTS

There were no complications to report for any of the cases during the surgical or post-surgical treatment; soft tissues appeared non-inflamed and healing was within normal limits for all cases.

The mean thickness changes at the 0-, 1-, 2-, and 3-mm measurement levels were  $0.03 \pm 0.83$ ,  $-0.2 \pm 0.54$ ,  $0.14 \pm 0.42$  and  $-0.07 \pm 0.33$  mm, respectively, reflecting a minimal mean gingival-depletion thickness at all levels. The free gingival-margin change ranged from a gain in height of 0.58 mm to a loss of  $-0.57$  mm. The mean gingival-margin change was minimal at  $0.04 \pm 0.43$  mm, reflecting stability over time (Table 1).

Radiographically, all cases showed a well-defined and present dentinal shield preserving the buccal plate of bone. The mean radiographic buccal plate thickness pre-operatively was  $0.78 \pm 0.11$  (range, 0.6–0.9 mm). The mean radiographic SS thickness post-operatively was  $2.04 \pm 0.6$  mm (range, 0.7–2.9 mm; Table 1).

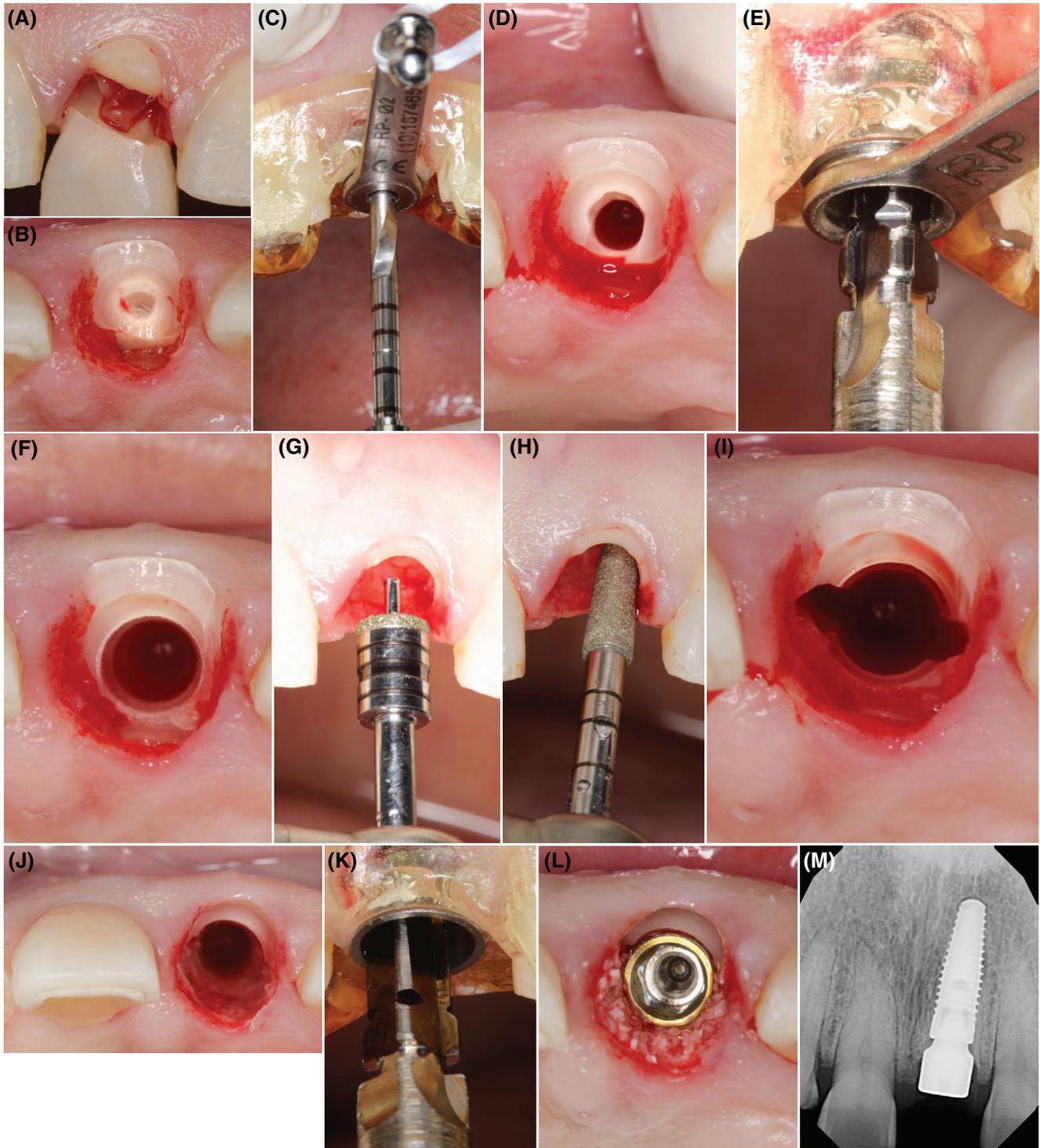
## DISCUSSION

The SS technique albeit a sensitive technique, has proven to be beneficial, particularly for implants placed in the esthetic zone.<sup>1–4</sup> The technique reported herein resulted in successful partial-extraction treatment in seven cases. It provides guided surgery as a tool to facilitate all SS steps and clinical procedures. The proposed technique shortens the time necessary to produce a dentinal shield and it provides an accurate optimal immediate implant position.

Together with the proposed technique, new instrumentation to drill through the tooth using guided burs of sequentially larger diameters to produce the dentinal shield, significantly eased the technique, as demonstrated in this report. The results showed minimal soft-tissue changes (mean thickness change from  $0.030 \pm 0.83$  to  $0.14 \pm 0.42$  and gingival margin change of  $0.04 \pm 0.43$  mm), denoting soft-tissue dimensional stability over time, with the longest case being 3.5 years. Comparable long-term results (5 years; oro-facial =  $-0.210 \pm 0.18$ , recession =  $-0.33 \pm 0.23$  mm) after SS have been reported by Bäumer et al.<sup>2</sup>

The observed presence of a dentinal shield protecting a buccal plate postoperatively, (mean radiographic buccal plate thickness of 2.04), together with the clinical soft-tissue stability for all cases, demonstrates the long-term beneficial effect of the SS technique. Our observations compare well with the results of other investigators.<sup>8,12,14</sup> The favorable clinical experience observed in these cases, has resulted in the authors performing this technique often and routinely in selected cases.

New technologies and digital planning of implants open new clinical possibilities.<sup>10,11</sup> Angled screw-channel abutment (ASCA) facilitates the digital and actual surgical position of implants concurrently allowing for a screw-retained restoration in the esthetic zone.<sup>10</sup> It must be pointed out that in our cases, ASCA was planned to enable an adequate implant position relative to the envisioned SS

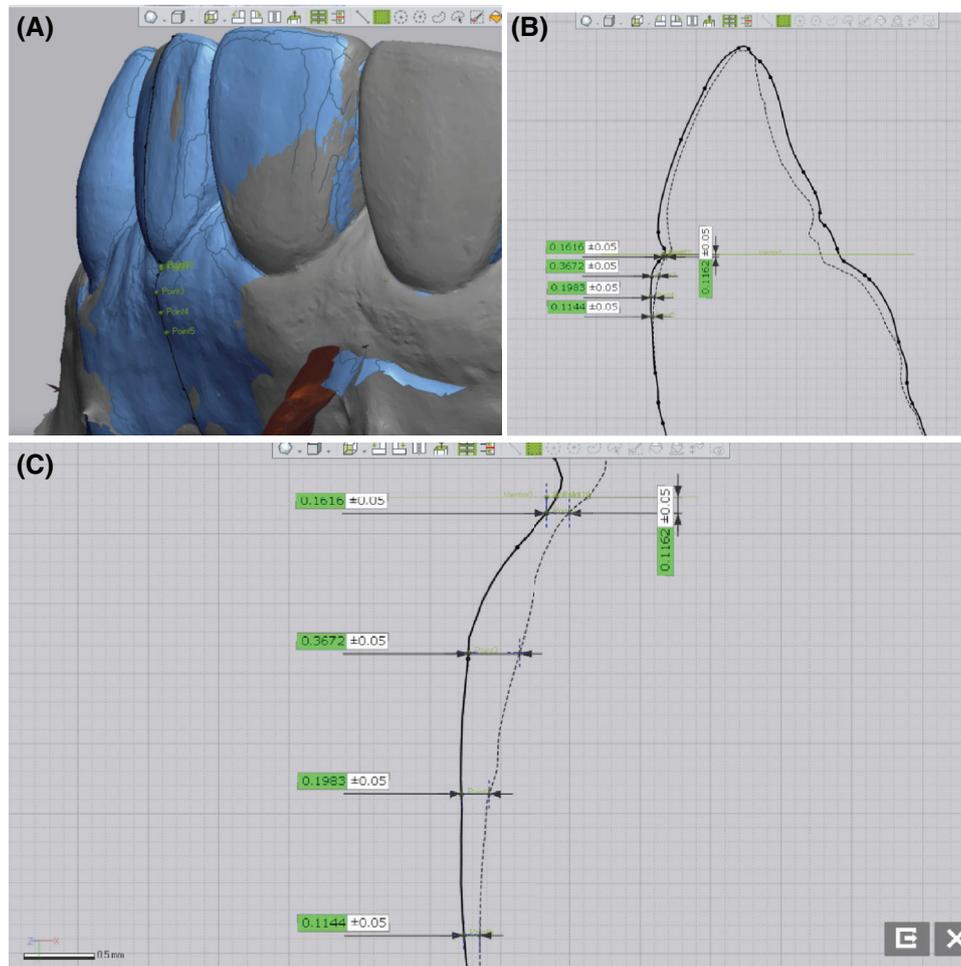


**FIGURE 3** Step-by-step surgical procedures; immediate implant placement, tooth extraction, and SS simultaneously being produced, as digitally planned previously. Procedures were executed utilizing the surgical guide, implant, and socket shield (SS) drills (C–K). The final clinical and radiographic outcomes (L–M).

and within the anterior maxillary osseous housing. Apico-coronal implant positions were planned at or below the crest of the bone, considering the prosthetic requirements for an esthetic restoration.

Digital implant planning positions for the cases were initially anatomically based, and then restoratively driven.

Therefore, it is recommended that the implant position should be determined first; once the ideal position is established, consideration is given to the (SS) sheet of dentin. Of biological importance, the implant and SS position relative to the bone crest will play a major role in the final healing and clinical outcome.



**FIGURE 4** (A) Pre- and post-operative stl files of intra-oral scans superimposed. (B) Assessment points of interest at mid-facial of tooth #10. (C) Distances measured between the pre-operative continuous line against the post-operative dotted line are seen. Note the minimal change after 3.5 years for all measurements.

During the actual surgery, the shield of dentin is finalized and adjusted to the crestal bone level, or below, as best as possible; thinned out to approximately 1.5 mm in width to allow for a space “gap” between the shield and implant, to favor healing. The apex of the teeth were always eliminated.

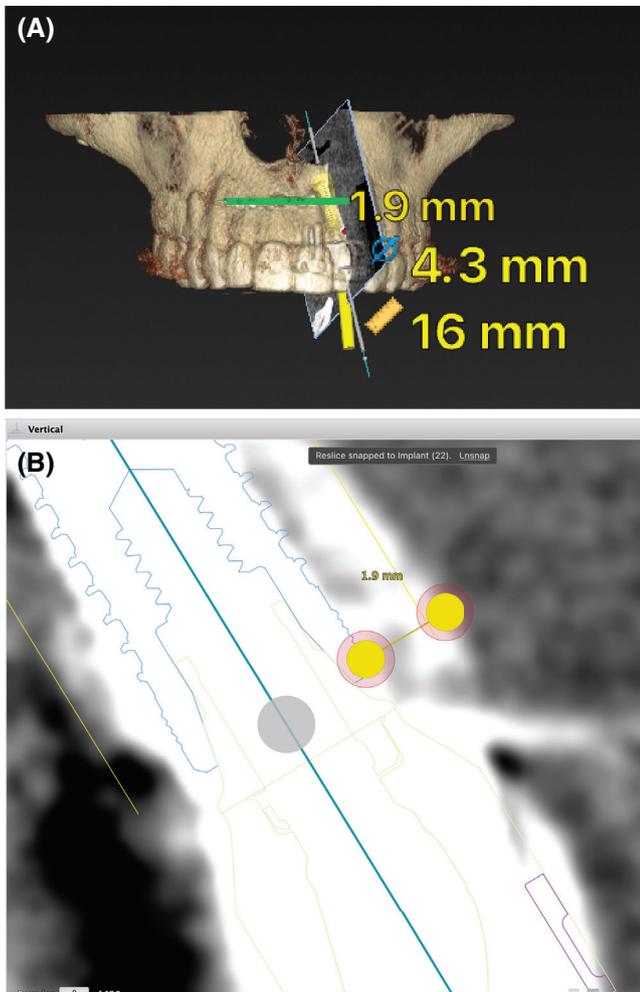
Among the challenges in the production of a dentinal shield are the carving of its dimensions, about 1.5 mm in width and 7–8 mm in length. In the authors opinion, the ideal socket-shield dimensions varies and are different for each patient, due to differences in tooth and alveolar anatomy found in each patient. The apical extent of the shield is controlled by carefully preparing the dentin with up and down sweeping motions, back and forth until satisfied with the dimensional extension. Specifically designed burs facilitates this task.

All of the cases were planned and treated similarly following the digital and clinical steps described. However, clinical challenges may intra-surgically arise, the technique works well for short-rooted teeth since it facilitates the extraction of the palatal aspect of the tooth and the drilling out of the apex. However, when encountered with longer roots,

removal of the apex, and the apical and lateral dentin relative to the dentinal shield might be a challenge. Direct vision of the osteotomy is recommended to identify the apex and the lateral dentin. Removal of the apex is best accomplished by drilling out the apex using a 2–3 mm long-shank round bur. Fine straight elevators are used to remove the palatal and lateral root remnants. The final shape of the shield is best accomplished with the specifically designed bur kit.

It is worth mentioning that for all cases, the shield of dentin started at or below the crestal bone, and not above the crest to support the supra-crestal soft tissues. Albeit this fact, dimensional supra-crestal soft tissue changes were minimal. Therefore, it seems that the preservation of the buccal plate plays an important role in supporting the stability of the buccal peri-implant soft tissues. In any of the cases, no attempt was made to support the interdental papillae with the extension to the shield mesially or distally.

In the authors’ opinion, a distance between the implant and the SS is desired to allow for grafting and to facilitate bone healing by allowing blood to fill the gap. Heavy



**FIGURE 5** (A) Radiographic sagittal cross-section “snapped” to a digital implant superimposed over the post-operative actual implant. (B) The distance measured between the implant and the outer aspect of the buccal plate. Note the robust presence of the socket shield (SS) after 3.5 years.

implant contact with the SS may dislodge it, which in turn may negatively alter wound healing. Unintentional light contact without dislodging of the SS might not be of consequence, particularly if the implant is placed sub-crestal. In a randomized clinical trial no differences were found between the results obtained from implants in direct contact with socket shields or when gaps were left but filled with a xenograft.<sup>15</sup>

Among the limitations of this case report are the various follow-up healing times at which the outcome variables were measured: the gingival thickness, gingival margin change, and the resulting radiographic SS (buccal plate) thickness. The follow-up times varied from 5 to 42 months with several cases with a relatively short healing time.

Thus, the long-term effect (5 years or longer) of the SS on the stability of the peri-implant soft tissues for these cases still needs further investigation.

The accuracy of guided surgery has been well documented. The error inherent in surgical guides is minimized

not only by the proper execution of the surgery but also by the proper acquisition of digital data. Thus, the accuracy of the actual implant position relative to the digitally planned position for all cases was assumed clinically within the range of error reported in the literature.

It should be pointed out that, whether or not cases are properly performed free-handed or by means of the digital SS technique, the expected clinical outcomes for both techniques should be similar. However, the aim of the computer-assisted SS surgery is to be more effective, and predictable, and simultaneously produce socket shields when placing immediate implants.

Meta-analyses,<sup>5,13</sup> randomized clinical trials,<sup>16–18</sup> and clinical retrospective studies<sup>19–21</sup> have proven the SS technique to be beneficial. The authors are aware of the limitation of this study with regard to the uncontrolled variables inherent in retrospective reports; however, the main purpose of this study was not to validate the SS technique but rather to describe and report on the advantages of a digitally supported SS technique. Further studies are needed to validate the advantages of this technique.

## CONCLUSION

Within the limits of this case series, the digitally planned guided socket-shield technique enables predictable immediate implant placement positions, facilitates the SS technique, and results in stable peri-implant soft and buccal hard tissues, at relatively short periods of time (5–42 months).

## AUTHOR CONTRIBUTIONS

Pedro M. Trejo: Conceptualization, data curation, formal analysis, writing—original draft, and writing – review & editing; Seiko Min: Data curation, formal analysis, and writing—original draft; Raysa Rivas: Data curation, and formal analysis. Pedro M. Trejo and Seiko Min agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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