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CASE STUDY

Guided roll flap in combination with static computer-assisted implant surgery: A technique report

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Abstract

Background: Peri-implant soft tissues are usually reduced when using a tissue punch in flapless static computer-assisted implant surgery (s-CAIS). The purpose of this article is to introduce a technique combining a minimally invasive guided roll flap (GRF) with s-CAIS to enhance buccal mucosal thickness and maintain peri-implant soft tissues.

Methods: A surgical template is used to define a crest-centered de-epithelialization window and to guide a palatal semilunar full-thickness pedicle that is rolled into a mid-buccal tunnel and stabilized. Osteotomy and implant placement are performed through the same template; the transmucosal profile is supported by an immediate provisional restoration, a sealing socket abutment, or an stock healing abutment. Clinical and volumetric outcomes were assessed over a 12-month follow-up.

Results: At 12 months, all implants demonstrated increased buccal mucosal thickness and adequate keratinized mucosa width. Volumetric analysis confirmed soft tissue volume augmentation compared to baseline. No vertical loss of adjacent papillae was observed. Clinical parameters, including PPD and BOP, remained stable, indicating maintained peri-implant health.

Conclusions: This technique demonstrates the feasibility of combining s-CAIS with specific surgical approaches to potentially maintain or slightly improve peri-implant soft tissues. It offers clinicians an alternative method to the soft tissue punch, so the peri-implant soft tissues may be maintained or even augmented in a minimally invasive way.

KEYWORDS

dental implant, minimally invasive surgical procedures, surgery, computer-assisted, surgical flaps

Key points

- Static-computer assisted implant surgery integration: bridges the gap between flapless implant surgery and soft tissue management/augmentation.
- Enhanced peri-implant soft tissues: combines s-CAIS and modification of tissue phenotype.
- Minimally invasive: reduced patient morbidity due to no need for additional grafting donor sites.

Plain language summary

Dental implants placed with flapless guided surgery can sometimes reduce the thickness of the surrounding peri-implant mucosa by the use of tissue punches. Soft tissues are essential for long-term implant health and appearance. This article presents a surgical approach that combines guided implant placement with a soft tissue management technique that repositions the site peri-implant mucosa to make it thicker instead of removing it. Using a surgical guide, the clinician knows exactly where to reshape the soft tissue and also use the same guide for implant placement. This minimally invasive approach helps to preserve or even improve the gum tissues around implants while maintaining the benefits of computer-guided surgery, potentially improving patient comfort and clinical outcomes.

INTRODUCTION

Soft tissue management around dental implants is crucial for both esthetic outcomes and long-term implant success.[1,2] The peri-implant phenotype encompasses a soft tissue component, formed by the keratinized mucosa width (KMW), mucosal thickness (MT), supra-platform tissue height (SPTH); and an osseous component, characterized by the peri-implant bone thickness (PBT).[3–5]

MT plays a main role in esthetics and the long-term peri-implant health. Moreover, inadequate MT is considered a risk factor for peri-implant soft tissue dehiscence (PISTD),[6,9] and can lead to the translucency of the transmucosal prosthetic components, which could compromise esthetic outcomes.[7,8] Furthermore, PISTDs can lead to a series of complications, including increased susceptibility to peri-implant diseases, and potentially compromising long-term treatment outcomes.[9,10]

The importance of peri-implant mucosa around implants was widely debated and is now largely recognized as a relevant factor for peri-implant health and stability. The lack of soft tissue thickness and KMW surrounding dental implants has been strongly associated with compromised peri-implant health.[11] KMW of $\geq$ 2 mm around dental implants helps reduce the risk and severity of peri-implant mucositis, marginal bone remodeling, and patient discomfort during brushing.[12]

Thus, various techniques for soft tissue augmentation have been described to address soft tissue deficiencies around implants,[13] including free gingival grafts (FGGs)[14] and connective tissue grafts (CTGs).[15] However, these methods require donor sites,[16] which can increase patient morbidity and post-operative discomfort, and add complexity to the surgical procedure.[17,18] Recently, advancements in digital dentistry and microsurgical techniques have introduced new methods for addressing these challenges. The integration of 3D imaging, computer-aided design and manufacturing (CAD/CAM), magnification, and minimally invasive surgical approaches offer the potential for more precise and less traumatic surgical procedures.[19]

Static computer-assisted implant surgery (s-CAIS) significantly improves the accuracy of implant placement,[20] and when indicated, it can be combined with a flapless approach. While several advantages regarding surgical invasiveness and postoperative morbidity have been associated with flapless implant placement, this technique restricts access to the surgical site, thereby limiting the ability to effectively manage the peri-implant soft tissues.[21]

When the flapless implant placement approach is used, a circumferential incision is commonly made to remove the mid-crestal soft tissue at the implant site without a surgical flap elevation, either with a rotatory tissue punch mounted on a surgical handpiece, or a circumferential incision utilizing a surgical blade. However, this approach inevitably implies the removal of some supra-crestal soft tissue at the implant site, often resulting in a reduction in width, or elimination of the keratinized mucosa around the implant. In addition, this procedure also leads to a reduction in MT—which corresponds to a decrease in soft tissue volume—as well as a reduction in the SPTH. This limitation can potentially compromise the clinician's ability to manage soft tissues effectively, particularly in cases requiring further augmentation or modification of the peri-implant mucosal architecture.[22,23] Therefore, it relies heavily on proper case selection and must be carefully balanced with fundamental biological principles and surgical techniques.[24,25] The roll flap technique was originally introduced by Abrams in 1980, and has since evolved into an effective method for soft tissue management around dental implants.[26]

The described technique aims to adapt the roll flap technique for integration with s-CAIS in a minimally invasive manner. It combines computer-assisted implant placement with a minimally-invasive microsurgical approach based on a full-thickness pedicled rolled flap to increase the peri-implant MT.

MATERIALS AND METHODS

This clinical technique article will describe a minimally invasive guided roll flap (GRF) dedicated to s-CAIS. It is designed

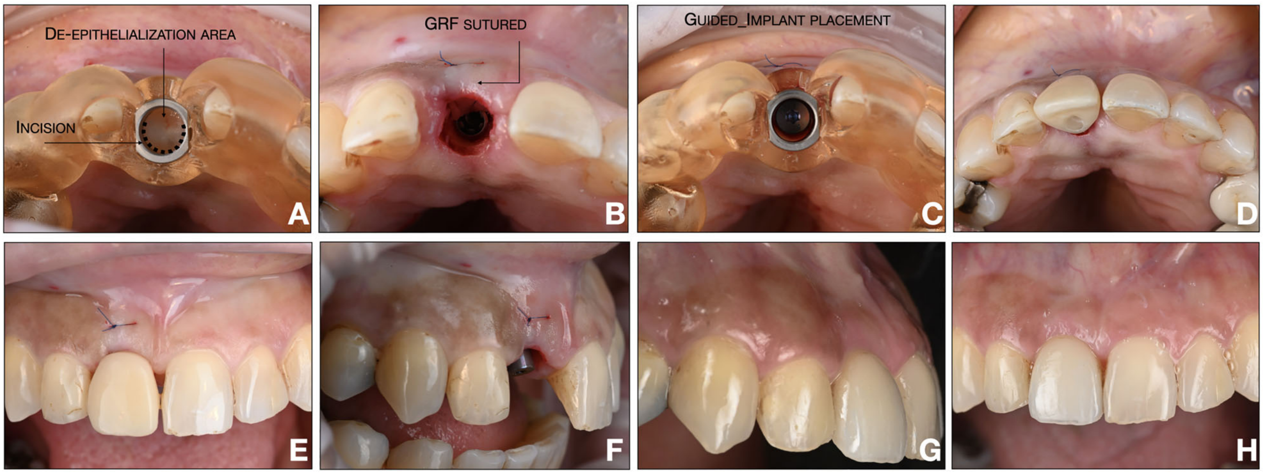

FIGURE 1 Guided roll flap (GRF) on an Implant with immediate provisionalization (CASE 1). (A) De-epithelization area and incision outline using the surgical guide. (B) GRF buccally sutured. (C) Surgical guide, healing abutment and suture. (D) Occlusal view implant provisional crown and buccal suture of pedicle flap. (E) Frontal view. (F) Lateral view implant position. (G) Lateral view implant supported restoration. (H) Frontal view final restoration 12-month follow-up.

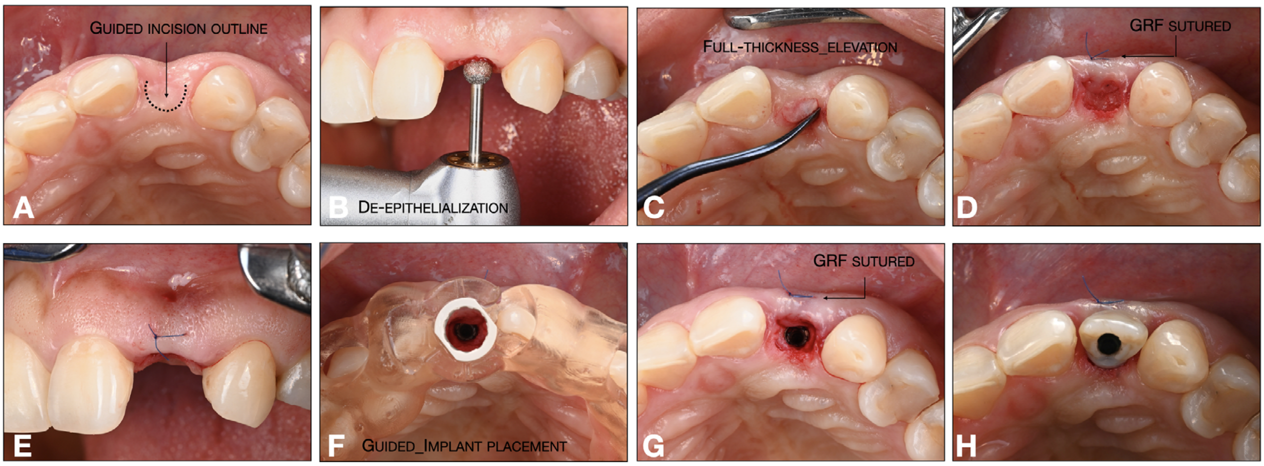

FIGURE 2 Guided roll flap (GRF) on an implant case with immediate provisionalization (CASE 2). (A) Baseline incision outline thanks to the surgical guide. (B) De-epithelialization of the soft tissue with a high-speed round diamond burr. (C) Full-thickness flap elevation of the de-epithelialized GRF. (D) GRF rolled into the buccal aspect and stabilized with horizontal mattress suture. (E) Buccal view. (F) Guided implant placement. (G) Occlusal view after implant placement and GRF sutured. (H) Immediate implant loading provisionalization.

to be employed simultaneously to implant placement in healed sites with minor soft tissue buccal deficiencies or second-stage surgeries. In this technique, after implant placement, an immediate implant supported restoration, sealing socket abutment (SSA)[27] or a conventional healing abutment can be used to prevent the buccal roll flap from collapsing.

Different clinical scenarios are described to showcase the advantages and versatility of the GRF, including implant placement with immediate implant-supported provisionalization (Figures 1 and 2) and implant placement combined with a SSA (Figure 3) or a conventional healing abutment (Figure 4). All patients were treated at the Harvard School of Dental Medicine and signed an informed consent regarding their participation in this investigation and to receive the surgical treatment. They were all followed for at least 12 months.

Digital planning and site preparation

Prior to surgical treatment, patients undergo diagnostic imaging using cone beam computed tomography (CBCT) (3D dental imaging system, Veraviewepocs 3D R100, J. Morita Mfg. Corp.) and intraoral scanning (IOS) (3D intraoral scanner, TRIOS 3, 3Shape A/S). Both Digital Imaging and Communication in Medicine (DICOM) and Standard Tessellation Language (STL) files were imported into a planning software (implant planning software, CoDiagnostix version 10.8, Dental Wings Inc.) where the dental implants' position was digitally planned according to the Bio-Restorative approach.[28] Then, a surgical template was designed and exported into an STL file that was later 3D-printed (3D printer, Form 3B, Formlabs Inc.) to perform s-CAIS. Local anesthesia was administered using 2% lidocaine with 1:100,000 epinephrine.

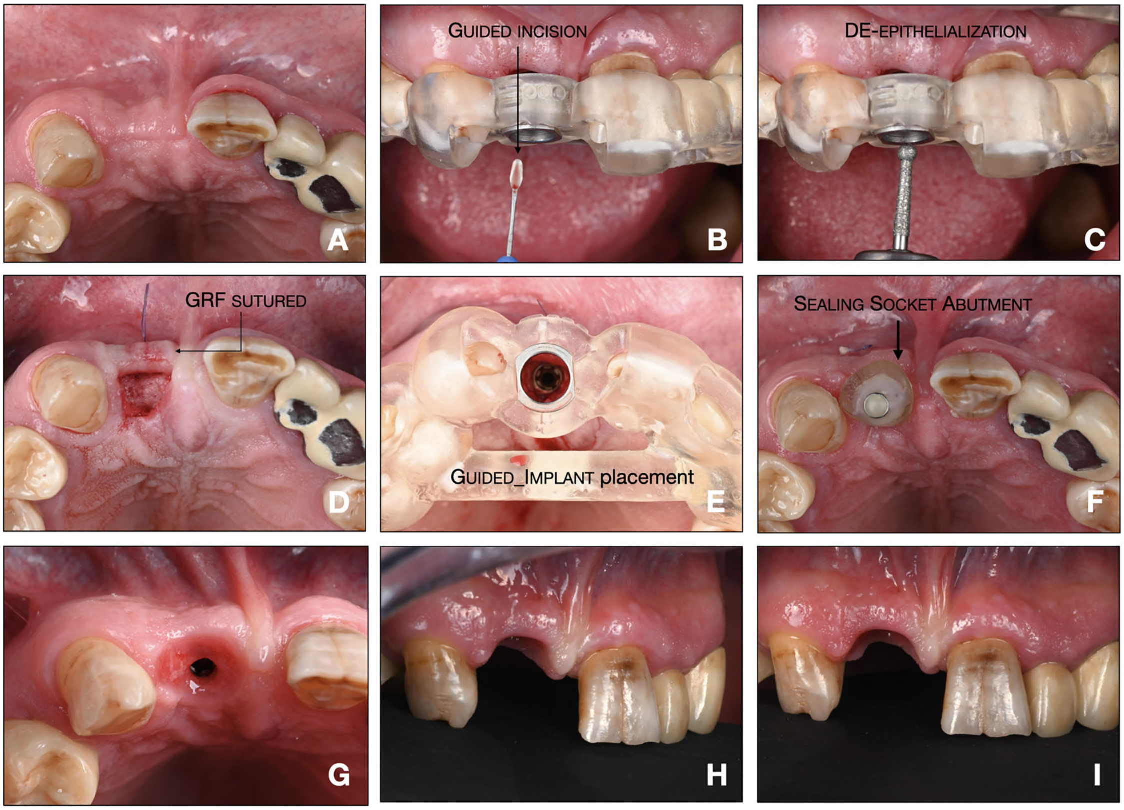

FIGURE 3 Guided roll flap (GRF) on an implant case with sealing socket abutment (SSA) (CASE 4). (A) Preoperative occlusal image of the site. (B) Incision outline using the surgical guide. (C) De-epithelialization of the soft tissue with a round diamond bur through the surgical guide. (D) Occlusal view of the GRF sutured on the buccal aspect. (E) Static computer-assisted implant surgery. (F) Sealing socket abutment 8 weeks after implant placement—occlusal view. (G) Peri-implant soft tissues at 8 weeks after SSA removal. (H) Lateral view of SSA + GRF emergence profile. (I) Frontal view.

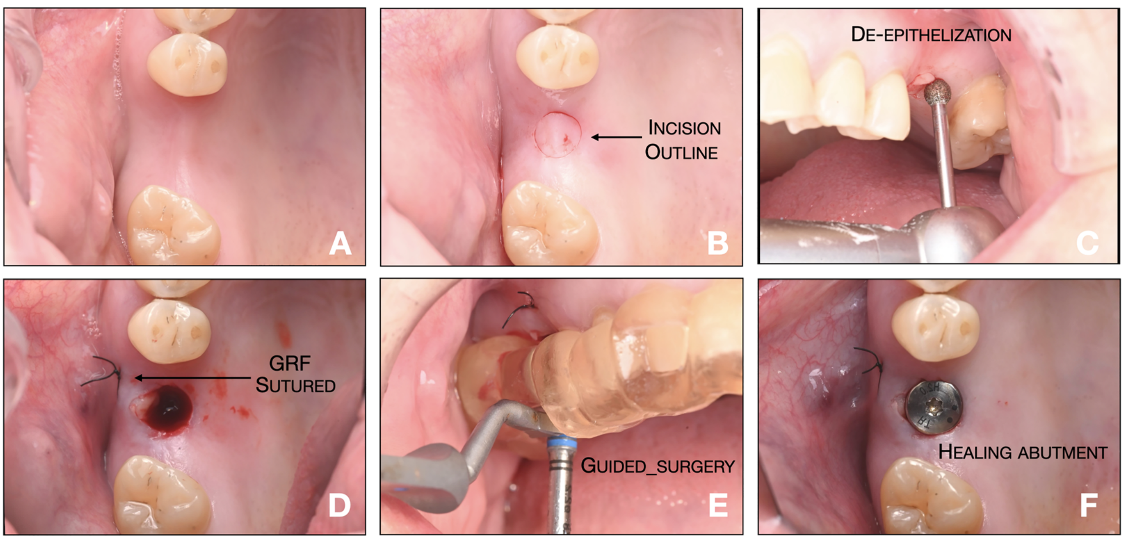

FIGURE 4 Guided roll flap (GRF) on implant placement type 4 with stock healing abutment (CASE 3). (A) Preoperative occlusal image of the site. (B) Incision outline guided by the surgical guide and 1 mm depth use of circular blade. (C) De-epithelization of outlined site. (D) Occlusal view of pedicle flap (GRF) sutured buccally. (E) Static computer-assisted implant surgery. (F) Healing abutment contributing maintaining the GRF with the suture in the buccal site.

De-epithelialization

Before proceeding with s-CAIS, the mid-occlusal aspect of the edentulous crest is de-epithelialized using a round fine diamond bur until light bleeding happened, meaning that the subjacent connective tissue had been reached. The exact area to de-epithelialize was precisely guided by the same surgical template designed for implant placement, to remove the epithelium only on top of the implant preparation site (Figure 2C).

Incision design

A microsurgical blade was used to create a full thickness semilunar incision around the palatal aspect, following the inner contour of the sleeve of the surgical template (Figure 2D). Afterward, the de-epithelialized area delimited by the semi-oval incision was elevated with care using a tunnelling instrument. This procedure facilitates access to the alveolar crest for implant placement and soft tissue management while preserving the adjacent papillae.

Full-thickness pedicle—elevation and mobilization

Once the full-thickness pedicle was elevated, it was rolled and extended into a small envelope created along the mid-buccal aspect of the edentulous ridge with a tunnelling instrument to an extent equivalent to that of the de-epithelialized surface. This approach allowed the occlusal de-epithelialized pedicle to be tucked beneath the mid-buccal mucosa of the edentulous site and stabilized with a 6-0 polyamide external horizontal mattress suture gaining additional buccal MT and partially or fully correcting the buccal soft tissue concavity (Figure 2F).

Implant placement

Once the implant was placed in a fully guided manner according to the manufacturer's guidelines (Figure 2I), prosthetic options may vary depending on the specific case requirements.

Immediate loading

This approach involves maintaining a configuration of the transmucosal complex using a provisional restoration on a titanium base (Figures 1 and 2L).

Immediate sealing socket abutment

When immediate loading is not intended or possible due to lack of primary stability, a SSA can be a useful option (Figure 4G) The transmucosal profile can be predesigned to guide soft tissue healing during the early stabilization of the emergence profile[29] (Figure 3).

Stock sealing abutment

A conventional healing abutment can also be used to maintain the newly gained soft tissue in the buccal aspect. This method enables later implant-level impressions and further modification of the transmucosal profile in future stages if necessary (Figure 4).

RESULTS

The healing process was uneventful in all cases, with minimal postoperative pain and swelling, and no signs of infection or flap dehiscence. At the final 12-month follow-up, the peri-implant soft tissue exhibited increased thickness in all cases and $\geq$ 2 mm width of keratinized mucosa around the implant site.[3] A volumetric analysis with no comprehensive quantitative analysis revealed that favorable outcomes were observed comparing the postoperative intraoral scan with the baseline using a specialized software, GOM Inspect 2019 (GOM GmbH) and Geomagic (D Systems) (Figures 5–7) (see Appendix 1).

Notably, there was no loss of vertical height in the adjacent papillae, which is crucial for maintaining the natural appearance of the gingival architecture. Clinical stability was observed, with no changes in probing pocket depth (PPD) and no bleeding on probing (BOP), further underscoring the health of the peri-implant tissues.

DISCUSSION

Following tooth extraction, significant morphological changes occur during the healing process of the alveolar ridge.[30] These changes can lead to combined horizontal and vertical ridge atrophies, resulting in soft tissue deficiencies that may compromise functional and esthetic outcomes for implant placement.[31] The described technique was presented as a contributing method to compensate for slight soft tissue horizontal deficiencies through a minimally invasive microsurgical technique. The findings of this clinical technique description article align with those of other recent studies, which have demonstrated that minimally invasive approaches to managing hard and soft tissue can optimize peri-implant health and stability.[32]

Several articles describe techniques for enhancing soft tissue around edentulous and peri-implant sites. These methods primarily aim to increase soft tissue volume using pedicle flaps, FGGs, or CTGs. Among these approaches, autogenous soft tissue grafting remains the preferred

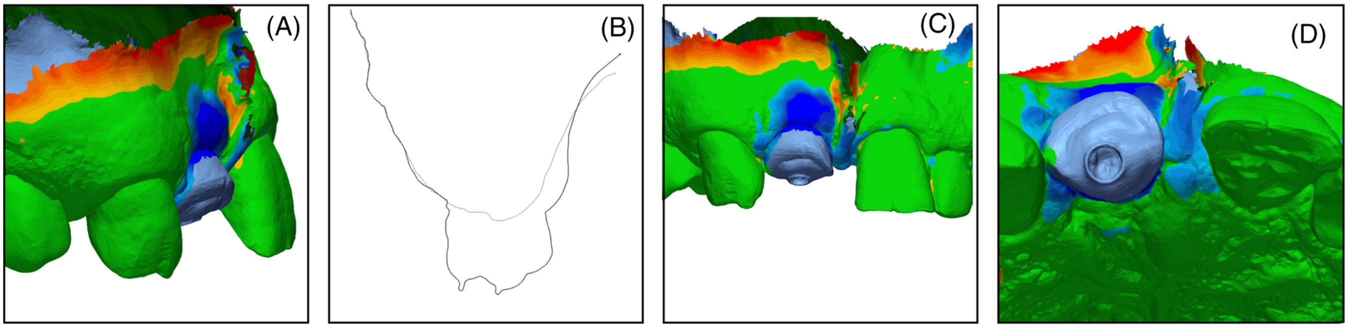

FIGURE 5 (A–D) STL files alignment and superimposition for a 3D assessment of volumetric changes between baseline and 12 months CASE 3. (A) Mean volumetric changes (mm) of the buccal contour from baseline to 12 months post-augmentation. (B) Linear dimensional changes (mm) of the midfacial soft tissue contour from baseline to 12-month follow-up. (C) Profilometric analysis depicting thickness changes (mm) of the midfacial peri-implant mucosa. (D) Volumetric changes of the midfacial contour from baseline to 12 months.

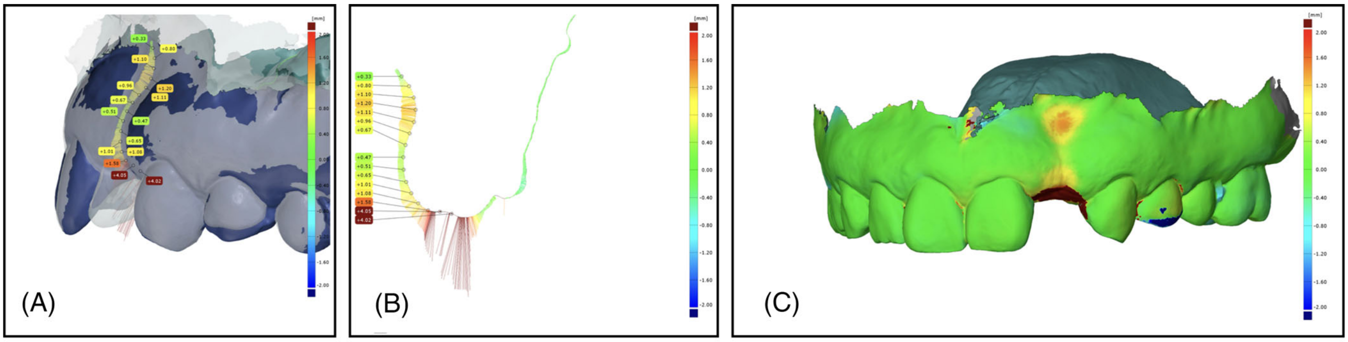

FIGURE 6 (A–C) STL files alignment and superimposition for a 3D assessment of volumetric changes between baseline and 12 months CASE 2. (A) Mean volumetric changes (mm) of the buccal contour from baseline to 12 months post-augmentation. (B) Linear and (C) profilometric changes.

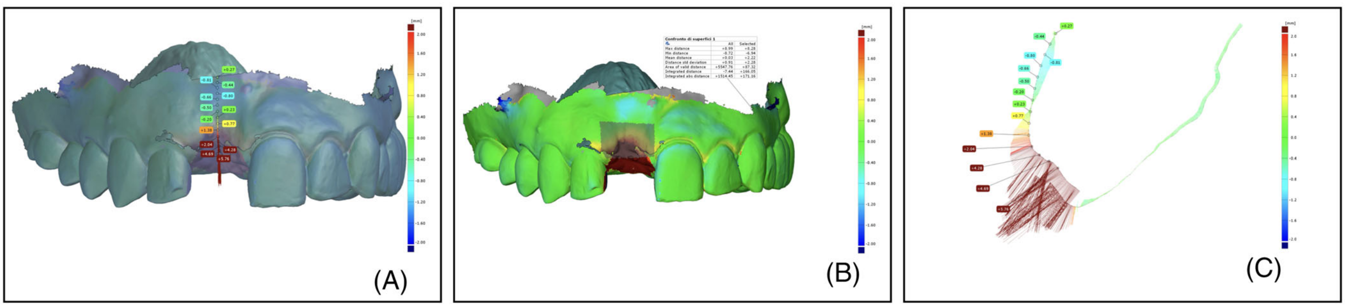

FIGURE 7 (A–C) STL files alignment and superimposition for a 3D assessment of volumetric changes between baseline and 12 months CASE 1. (A) Mean volumetric changes of the view of the buccal contour from baseline to 12 months post-augmentation. (B) Profilometric and (C) linear analysis depicting thickness changes of the midfacial peri-implant mucosa.

choice, as it is considered the gold standard due to its reliability and long-term stability.[17] Although multiple approaches to reduce the invasiveness of palatal tissue harvesting have been proposed,[33] the roll flap technique still represents a valid alternative since it avoids palatal harvesting, while still enhancing the peri-implant mucosa with autogenous tissue.

This technique utilizes the s-CAIS surgical template to precisely identify the implant placement site, enabling a minimally invasive de-epithelialization with a diamond bur. This situation not only allows to increase the buccal soft tissue volume but also contributes to the preservation of adjacent papilla height.

Clinical studies demonstrate that achieving a minimum MT of 2 mm is crucial for preventing mucosal discoloration and maintaining optimal esthetic outcomes around implant-supported restorations. Therefore, proper management of peri-implant mucosa plays a crucial role in preventing complications.[34] These interventions have also been shown to limit marginal bone loss and reduce the incidence of BOP over the long term.[35]

The innovative component of this technique lies in the accurate placement of the roll flap exactly where the implant will be inserted thanks to the digital planning and s-CAIS. This modification offers some advantages over the traditional roll flap techniques and regular flap procedures: (1) it is minimally invasive and does not require an additional donor site; (2) de-epithelialization is performed only in the targeted area; (3) the papillae are entirely preserved, as they are not elevated during surgery; and (4) it enables the use of a minor flap for access for implant placement in sites where the flapless approach was previously contraindicated due to reduced keratinized tissue width (KTW); and lastly (5) its design is reversible, if intraoperative complication arise or further augmentation procedures need to be performed, the flap can be converted into a traditional flap design without comprising primary closure of the surgical site.

Furthermore, when using free autogenous soft tissue grafts, it is essential to consider that shrinkage during healing may range from 25% to 45%.[36] In contrast, the roll flap technique, which maintains vascularization, typically experiences less shrinkage, leading to more stable results.[37]

Flapless approaches, often using tissue punches, offer minimal invasiveness by sacrificing keratinized tissue (KT) and soft tissue volume, potentially compromising long-term outcomes. In contrast, the roll flap technique aims to "recycle" the soft tissue on top of the implant, preserving this volume for horizontal augmentation. While this roll flap technique uses a CAD/CAM surgical template and therefore could be considered more technique sensitive, it provides greater control over the available soft tissue and reduces the invasiveness of the surgery.

Managing peri-implant buccal deficiencies requires a systematic approach based on the PBT and the specific clinical scenario. When PBT is insufficient or when bone grafts are required for other purposes, bone augmentation procedures are recommended.[38] In cases where PBT is adequate, soft tissue grafting options, including CTGs and soft tissue substitutes, should be considered, and minimally invasive flaps as the one proposed in this manuscript, can become a valuable tool for clinicians.[39]

However, this technique also has limitations since it is primarily indicated for mild to moderate soft tissue horizontal deficiencies and may not be suitable for severe situations. While the GRF can improve horizontal deficiencies and maintain gingival margin levels, it does not significantly improve interdental papillae levels. If additional buccal tissue augmentation is required, the de-epithelized area can be extended beyond the implant entry point towards the palatal aspect to obtain a bigger flap, however its effect is yet limited. Despite these limitations, it remains a valuable tool for clinicians seeking to enhance peri-implant soft tissue contours and thickness in suitable cases in a simple and minimally invasive way, particularly when combined with computer guided implant placement.

Although this technical description may be valuable for clinicians in understanding the potential of this approach, future well-designed prospective randomized clinical trials are required to better evaluate this technique. Statistical comparisons with other similar techniques described in the literature are also necessary. The current digital analysis serves only as a visual reference for case evaluation and to facilitate interpretation of the results; however, it cannot be considered an objective measure due to statistical limitations.

CONCLUSIONS

This clinical technique description introduces a method that integrates s-CAIS with a minimally invasive full-thickness pedicle roll-flap design to enhance buccal peri-implant soft tissue outcomes. Considering the limitations of the described technique and the limitations of this article, this approach demonstrates a straightforward method for increasing buccal MT in mild and moderate soft tissue horizontal deficiencies while implants are placed by s-CAIS.

AUTHOR CONTRIBUTIONS

Ignacio Pedrinaci: Conceptualization (lead); methodology (lead); formal analysis (lead); investigation (lead); supervision (lead); writing—original draft (supporting); writing—review and editing (lead). **Javiera Casas**: Writing—original draft (lead); investigation (supporting); writing—review and editing (equal). **Samuel Akhondi**: Writing—review and editing (supporting). **Javier Calatrava**: Writing—review and editing (supporting). **David Palombo**: Writing—review and editing (supporting). **Alejandro Lanis**: Writing—review and editing (supporting). **German O. Gallucci**: Supervision (supporting); approval of final manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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APPENDIX 1

Model Analysis

Baseline (T0) and 12-month (T12) intraoral scans were exported as STL files and were imported into a mesh-analysis software (GOM Inspect 2019, Braunschweig, Germany). All analyses were performed by a single calibrated examiner. A second software (Geomagic, 3D Systems, Rock Hill, SC, USA) was used to visualize sections when needed; no alignment was performed outside the mesh-analysis software. For each case, the T0 and T12 meshes were trimmed to a standardized region of interest (ROI) extending from the mesial to distal base of the of the edentulous site and from the mucosal margin coronally to 6 mm apically on the buccal aspect. Mobile tissues outside the ROI and scan artifacts were excluded. Stable reference areas like the adjacent enamel and palatal/lingual soft tissues ≥5 mm away from the surgical site were masked to drive the alignment and applied identically to T0 and T12.

T12 was registered to T0 using the softwares pre-alignment followed by a constrained best-fit (iterative closest point) restricted to the masked reference surfaces (30 iterations; convergence threshold 0.01 mm; 3σ outlier rejection). Alignment quality was verified by the RMS error on the masked references; datasets with RMS > 0.10 mm were re-aligned until ≤ 0.10 mm was achieved. After registration, a comparison (T12–T0) was computed within the buccal ROI. The following descriptive outputs were recorded using the softwares analysis table and the areal percentage showing ≥ 0.25 mm buccal gain. The color scale was set from −2.0 mm (blue) to +2.0 mm (red), with green indicating near-zero change. A mid-buccal sagittal section was created orthogonal to the tooth, passing through the center of the edentulous crest at T0. On this plane, the software was used to generate the 2D intersection for T0 and T12. A crest reference point was placed at the T0 mucosal crest on MB. From this crest, four apico-coronal measurement levels were defined along the section. At each level, the distance from T12 to T0 was computed. By convention, positive values denote buccal convexity/thickness gain and negative values represent loss.