

CASE STUDY

Vertex technique: A novel microsurgical technique for papilla reconstruction—Case study

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Abstract

Background: Interdental papilla is key to gingival health and esthetics. Its loss leads to black triangles, which affects the smile's appearance and increases periodontal risks. Various treatments have been proposed, but papilla reconstruction remains challenging due to anatomical and vascular limitations. This case report aims to describe the vertex technique (VT), a novel approach combining tunneling with connective tissue and bone grafts for papilla reconstruction.

Methods: VT was performed on patients with papilla presence index (PPI) 3 and 4 defects and a thick gingival phenotype in the esthetic zone. A microsurgical approach was employed to create an interproximal tunnel, thereby minimizing tissue trauma and preserving the vascular supply. Custom-shaped connective tissue grafts were inserted to enhance soft tissue volume, while bone grafts targeted interproximal bone loss for additional support. The procedure emphasized careful flap management to optimize healing and graft stability. All patients were periodontally treated prior to surgery and were healthy at the time of the procedure.

Results: VT achieved significant papilla augmentation, reducing the visibility of the black triangles, and improving gingival esthetics, from PPI 3 or 4 to PPI 2 after treatment. The integration of connective tissue and bone grafts resulted in enhanced soft tissue volume and long-term stability observed over follow-up periods of 1–5 years.

Conclusion: The VT offers a promising solution for interdental papilla defects PPI 3–4, addressing both soft tissue and bone deficiencies. Its combination of microsurgical tunneling with grafting provides esthetic and stable results, expanding treatment options in periodontal plastic microsurgery.

KEYWORDS

alveolar bone grafting, connective tissue, papilla reconstruction, periodontal disease, periodontal plastic microsurgery, tissue graft

Key points

- Vertex technique (VT) combines microsurgical tunneling with connective tissue and bone grafts to reconstruct interdental papillae with high precision and minimal trauma.
- Significant esthetic improvement and stable papilla height were achieved in papilla presence index 3–4 defects, with outcomes maintained over 1–5 years.
- VT is indicated for healthy, periodontally treated patients with thick phenotypes, although it requires advanced skills and resources for proper execution.

Plain language summary

This study introduces the vertex technique, a new method to fix gaps (black triangles) between teeth caused by the loss of the interdental papilla. These gaps not only affect the look of a smile but can also harm gums' health. The technique uses a microsurgical approach to insert connective tissue and bone grafts, improving both soft tissue volume and bone support. It was used on patients with severe defects in the esthetic zone. Results showed a significant improvement in appearance and long-term stability, with no complications. The vertex technique offers a promising solution for these periodontal issues.

INTRODUCTION

The interdental papilla is a key anatomical structure of the gingiva, filling the embrasure space between adjacent teeth and playing an essential role in the esthetic integration of the gingival tissues with the teeth.¹ Its loss results in “black triangles”, which negatively impact smile esthetics and periodontal health.^{2–4} These spaces are highly noticeable and undesirable; even laypeople with a low smile line can detect papilla loss, and 98% indicate a preference for maintaining intact, healthy papillae without any loss.⁴ This underscores the papilla's critical role in an esthetically pleasing smile, making its preservation a clinical priority.^{4,5}

Papilla morphology and position depend on various factors, including tooth position, bone crest architecture, vertical distance from the proximal alveolar bone crest to the interproximal contact point, gingival inflammation, phenotype, attachment level, and festooning.^{6–9} Even in a clinically stable periodontal condition, papilla loss may result from malpositioned teeth, tooth shapes, poor restorations, surgical trauma, or periodontal disease and its treatment.² Papilla loss compromises interproximal hygiene, promoting biofilm retention and thereby increasing the risk of periodontal inflammation or disease. Additionally, exposure of root surfaces may lead to phonetic alterations and dentin hypersensitivity.^{2,9,10}

To classify interdental papilla defects and guide treatment, the Cardaropoli classification uses clinically relevant parameters—papilla shape, cementoenamel junction (CEJ) relation, and adjacent teeth—summarized in the papilla presence index (PPI), which ranges from 1 to 4 (Figure 1).¹¹

A systematic review performed by Patel et al. found that surgical procedures incorporating connective tissue grafts (CTGs) provide the strongest evidence for minimizing long-term loss of reconstructed papilla.¹² The most used techniques involving CTG are coronally advanced flap and tunneling (interproximal tunnel with customized grafts).¹³ Coronally advanced flaps: these flaps are used in conjunction with CTG and other biomaterials to achieve root coverage and promote the regeneration of soft tissues, as clinically evidenced by gains in clinical attachment level (CAL). Their implementation is key to optimizing the outcomes in periodontal rehabilitation procedures.^{7,9,13} Tunneling technique described by Feuillet et al. represents

a significant improvement in periodontal microsurgery.¹⁴ It combines interproximal tunnels with CTG specifically designed for each patient. This strategy has proven effective in interdental papilla reconstruction, highlighting the critical roles of vascularization and both surgical refill of the interdental space and precise mucosal tissue handling to support volume stability.¹⁵

When papilla loss involves interproximal bone, bone reconstruction would be desired. However, soft tissue techniques do not address bone regeneration. While intrabony defect regeneration is documented, there is no evidence for treating osseous defects of the interdental alveolar crest.¹⁶

Given the limited treatment options, this case report introduces a novel interdental papilla augmentation approach—the Vertex technique (VT). Unlike conventional techniques, this approach combines the tunneling technique with CTG and incorporates a regenerative component through the use of bone grafts (Table 1). The VT was applied in periodontally treated patients presenting with PPI 3–4 defects and a thick gingival phenotype.

CASE REPORTS

Clinical presentation

This case report follows the CARE guidelines (for case reports).¹⁷ Three healthy American Society of Anesthesiologists physical status scale I (ASA I) patients (one man and two women: in case 1, the patient was 25 years old; in case 2, the patient was 37 years old; and in case 3, the patient was 45 years old) were treated at the Pommer–Durán–Pino clinic in Santiago, Chile, between 2019 and 2023. All patients were non-smokers, had previously been treated for stage II–III grade B periodontitis, and were enrolled in periodontal maintenance therapy. They presented with PPI 3–4 defects, according to the Cardaropoli classification, exhibited a thick gingival phenotype, and showed full-mouth plaque and bleeding on probing (BOP) scores below 10%, as well as stable probing depths (PDs) and CAL (Table 2).^{11,18} Case 1 is described in detail up to its 1-year follow-up (Figure 2), while cases 2 and 3 are presented at baseline and their final follow-ups at 2 and 5 years, respectively.

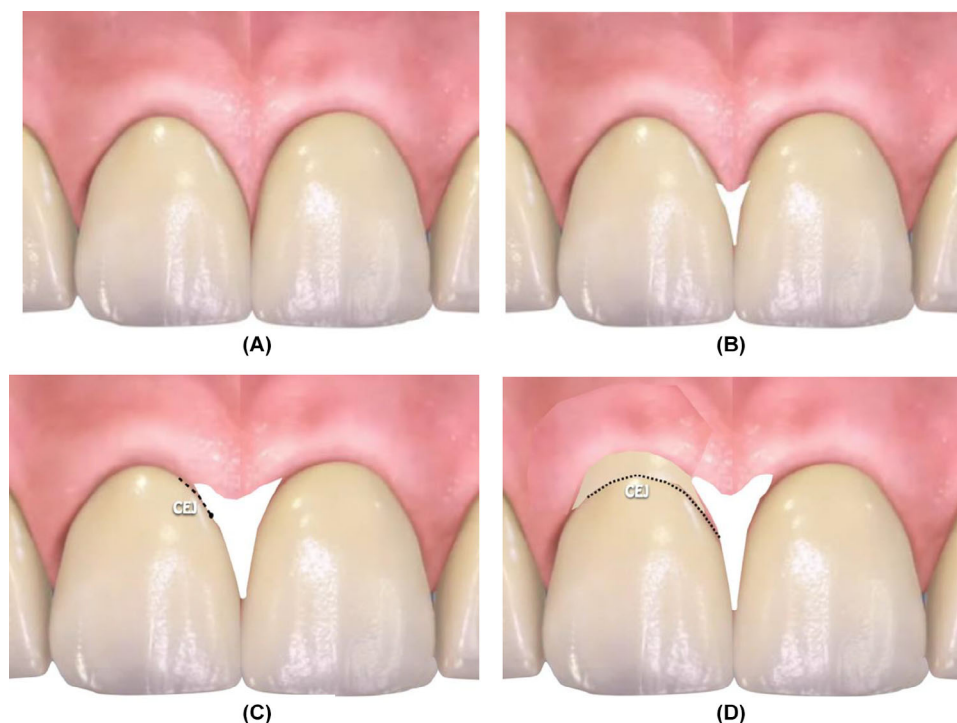


FIGURE 1 Cardaropoli classification. (a) Papilla presence index (PPI) 1: papilla is completely present. (b) PPI 2: papilla is no longer completely present, but the interproximal cemento-enamel junction (CEJ) is still not visible. (c) PPI 3: papilla is no longer completely present and the interdental CEJ is visible. (d) PPI 4: papilla is no longer completely present and the buccal and interdental CEJ are visible.

Clinical management

For diagnostic purposes, cone beam computed tomography (CBCT), panoramic and periapical radiographs, as well as intraoral photographs were obtained for all cases. Digital impressions were captured using an intraoral scanner (Sirona Dental System) and saved as Standard Tessellation Language (STL) files using specialized software (Cerec SW4.4, Sirona Dental System) in case 1. Due to the antiquity of cases 2 and 3, the technology was not yet available at the time in the clinic. The VT surgery was indicated and performed in all cases for the reconstruction of the interdental papilla between the upper central incisors (teeth 8 and 9).

Surgical phase

Using magnification between 3.5× (Univet Loupes, Minoprio) and 12× (Omni Pico Zeiss), all VT surgeries were performed by the same periodontist surgical team, following the six steps described below.

1. Tunnel preparation: local anesthesia was administered using lidocaine with epinephrine (1:100,000) via local infiltration in the vestibular and palatal areas of the surgical site. Transpapillary and intrasulcular injections were avoided to limit vasoconstriction. Intracrevicular incisions were made with a #15c scalpel (Swann Morton, Sheffield) to create a mucogingival tunnel. First, a

full-thickness vestibular flap was elevated at the gingival margin of the involved teeth using a TKN2 instrument (Hu-Friedy). Next, to release all muscle attachments and facilitate coronal advancement of the tissue, a partial-thickness flap was created with a microblade (Keydent microblade tunnel), employing fan-shaped movements along the mucogingival line. Finally, the papillae were carefully elevated in an apico-coronal direction until displacement of the flap toward the coronal and palatal areas was achieved (Keydent microblade tunnel, American Dental Systems GmbH). This sequence was performed to reduce tension on the full-thickness flap and minimize the risk of papillary tearing (Hu-Friedy) (Figure 3). The tunnel preparation was performed entirely under 8× magnification.

2. Preparation of the donor site: a CTG was harvested from the palatal tuberosity. The donor site was sutured using 5-0 expanded polytetrafluoroethylene (6/0 PTFE, A Surgical) sutures with a cross-mattress technique. The preparation of the donor site was performed entirely under 3.5× magnification (Univet Loupes, Minoprio).
3. Insertion of the CTG: prior to graft insertion, careful root planing of the exposed root surfaces was performed as a root surface conditioning step (Grace Sub-0, Hu-Friedy). The graft was designed to fit the interproximal space of the papillae and fixed with two vectors vestibular and palatal using 7-0 polypropylene sutures (7/0 PTFE, Ad Surgical) with a cross-mattress technique (Figure 4). Once positioned, the suture was tied on both

TABLE 1 Comparison among different surgical techniques proposed for interdental papilla reconstruction.

Graft	Author, year	Study design	Follow-up period	Surgical technique	Outcomes reported
CTG + BG + RM	Vertex technique	Case study	1–5 years	A microsurgical approach was used to create an interproximal tunnel. Custom-shaped CTG was inserted to enhance soft tissue volume, while bone graft targeted interproximal bone loss for additional support.	Improved in papilla height in all the treated cases
CTG	Sharma et al. 2017	Case series	6–11 months	Partial thickness flap with two vertical incisions away from the line angles of the involved teeth, coronal displacement of the papillary unit. CTG harvested from the palate was stabilized in the created void between the soft tissue and the bone. Periodontal dressing applied.	PD changes: 0.27 mm CAL gain: 0.41 mm Vertical reduction: 37.01% Horizontal reduction: 37.66% Area of black triangle reduction: 60.26%
CTG	Kaushik et al. 2014	Case series	6–15 months	Semilunar buccal incision, detachment of the soft tissue with the Orban Knife. Insertion of the CTG.	Mean distance from the contact point to the gingival margin significantly decreased
CTG	Feuillet et al. 2018	Case series	2–3 years	Full thickness tunnel technique with parallel releasing incisions made on the palatal side (and split-thickness). CTG trimmed and inserted into the flap and papilla coronally advanced.	Improved in papilla height all the treated cases
CTG	Carnio and Carnio 2018	Case reports	1–10 years	Interdisciplinary (periodontic-orthodontic-restorative) approach. Following approach: split-thickness semilunar incision 2 mm. Coronal to the mucogingival junction and intrasulcular incision with fully preservation of the papilla. A buccal/palatal void was created and filled with CTG harvested from the palate/tuberosity.	PD change: 2 mm for tooth #7 and no change for tooth #8 REC reduction: 4 mm KT gain: 2 mm for tooth #7, 1 mm for tooth #8
CTG	Carnio et al. 2004	Case reports	1–4 years	Semilunar buccal incision, detachment of the soft tissue with de Orban knife, insertion of the CTG. Two other similar surgical procedures were performed in the same area over time.	Completed papilla reconstruction
CTG	Nemcovsky et al. 2001	Case reports	14 months	Semilunar buccal incision, detachment of the soft tissue with Goldman-fox knife, insertion of the CTG.	PIS ranged from 0 to 2 preoperative (mean 1.0) and between 1 and 3 postoperative (mean 2.2)

Note: Comparison between surgical techniques described in the literature and their main outcomes. Adapted from Rasperini et al.²

Abbreviations: BG, bone graft; CAL, clinical attachment level; CTG, connective tissue graft; KT, keratinized tissue; PD, probing depth; PIS, papilla index score; REC, recession; RM, resorbable membrane.

the vestibular and palatal sides to prevent any movement (Figure 5). The insertion of the CTG was performed entirely under 12× magnification (Omni Pico Zeiss).

4. Placement of the resorbable membrane: a resorbable membrane (Mem-lok, BioHorizons) was adapted to the palatal and buccal interproximal surfaces and fixed with three vectors using mattress sutures: two on the buccal side and one on the palatal side (Figure 6). Once positioned, suturing began on the palatal side, followed by the distal and mesial sites (Figure 7). The placement of the resorbable membrane was performed entirely under 8× magnification.
5. Insertion of the bone graft: the flap was elevated, and particulate allographic bone (MinerOSS, BioHori-

zons) was placed in the interproximal and facial areas (Figure 8). The insertion of the bone graft was performed entirely under 8× magnification.

6. Final suturing of the flap: the tunnel flap was sutured to the teeth with suspension sutures anchored on the palatal side during the first pass. This technique enabled coronal and palatal displacement of the flap using 6-0 or 7-0 polypropylene sutures (6/0, 7/0 AD Surgical) (Figure 9). To finalize, a double-crossed suture (6/0, 7/0 AD Surgical) was placed, anchored at the incisal contact points of teeth 8 and 9, crossing through both the buccal and palatal aspects (Figure 10).¹⁹ The final suturing of the flap was performed entirely under 12× magnification.

TABLE 2 Clinical assessments of periodontal parameters.

Baseline					12 months						
Case 1											
BOP	(–)		(–)								
PPI	3		2								
S3D			1.47								
	Baseline		12 months		Change CAL						
	PD	CAL	PD	CAL							
Tooth 8											
MB	3	3	3	1	2						
B	2	2	2	2	0						
DB	4	4	4	4	0						
MP	2	2	3	1	1						
P	2	2	3	2	0						
DP	5	2	3	2	0						
Tooth 9											
MB	3	3	3	1	2						
B	2	1	3	1	0						
DB	3	2	3	2	0						
MP	3	2	3	1	1						
P	3	2	3	2	1						
DP	3	2	3	3	0						
Baseline			12 months		24 months						
Case 2											
BOP	(–)		(–)		(–)						
PPI	3		2		2						
S3D			1.53		1.53						
	Baseline		12 months		24 months		Change CAL				
	PD	CAL	PD	CAL	PD	CAL					
Tooth 8											
MB	3	2	3	1	3	1	1				
B	3	1	3	1	3	1	0				
DB	3	2	3	2	3	2	0				
MP	3	3	3	1	3	1	2				
P	3	1	3	1	2	1	0				
DP	3	2	3	2	3	2	0				
Tooth 9											
MB	3	3	3	1	3	1	2				
B	3	2	3	2	3	2	0				
DB	2	2	2	2	2	2	0				
MP	3	3	3	1	3	1	2				
P	3	1	2	1	3	1	0				
DP	3	2	3	2	2	2	0				
Baseline		12 months		24 months		36 months		60 months			
Case 3											
BOP	(–)		(–)		(–)		(–)		(–)		
PPI	4		2		2		2		2		
	Baseline		12 months		24 months		36 months		60 months		Change CAL
	PD	CAL	PD	CAL	PD	CAL	PD	CAL	PD	CAL	
Tooth 8											
MB	3	7	3	4	3	4	3	4	3	4	3
B	2	4	2	3	2	3	2	3	2	3	1
DB	4	6	3	3	3	3	3	3	3	3	3
MP	3	6	3	4	3	4	3	4	3	3	3

(Continues)

TABLE 2 (Continued)

	Baseline		12 months		24 months		36 months		60 months		Change CAL
	PD	CAL	PD	CAL	PD	CAL	PD	CAL	PD	CAL	
P	3	4	3	4	3	4	3	4	3	4	0
DP	3	5	3	5	3	5	3	5	3	5	0
Tooth 9											
MB	4	6	3	3	3	3	3	3	3	3	3
B	2	4	2	3	2	3	2	4	2	3	1
DB	3	4	3	4	3	4	3	3	3	4	0
MP	3	4	3	3	3	3	3	3	3	3	1
P	3	3	3	3	3	3	3	3	3	3	0
DP	3	4	3	4	3	4	3	4	3	4	0

Note: Clinical measurements recorded before and after treatment to evaluate periodontal status and papilla reconstruction.

Abbreviations: B, buccal; BOP, bleeding on probing; CAL, clinical attachment level; DB, distobuccal; DP, distopalatal / distolingual; MB, mesiobuccal; MP, mesiopalatal / mesiolingual; P, palatal / lingual; PD, probing depth; PPI, papilla presence index score; S3D, superimposition 3D models.

Postoperative care

Postoperative care included 100 mg ketoprofen twice daily for 72 h, 875 mg amoxicillin twice daily for 7 days, and 0.12% chlorhexidine mouthwash twice daily for 7 days. Brushing was avoided in the surgical area for 2 weeks. Sutures were removed after 15 days, and regular follow-ups were scheduled (Figure 11). Clinical parameters were reevaluated annually, with follow-up periods ranging from 1 to 5 years. Patients were advised to use gentle flossing instead of interdental brushes to prevent trauma.

STL file acquisition, overlapping, and vertical height measurements

Digital impressions were captured (Sirona Dental System) in case 1 using an intraoral scanner and saved as STL files using specialized software (Cerec SW4.4, Sirona Dental System). STL files were imported into image analysis software (Medit Desing 2.1.4.97 Meditcorp) for further evaluation (Figure 12a). Measurements were performed by a calibrated examiner (C.A.) to ensure consistency. The overlapped STL models (initial and final) were placed at the maximum zoom scale, with the teeth's central axis parallel to the view angle and rotated to a mesial view. The cut tool from the Analyzing Tool menu was then activated. Using the Deviation Display Mode tool, a line was created using the Create Section Lines tool. Then, the STL files were hidden, leaving only the lateral view of the obtained silhouette (Figure 12c), where measurements were performed using the Measure Distance by Two Points tool. This line lingered through the midline, parallel to the tooth's central axis, crossing the most coronal area of the papilla. Two measurements were performed, one from the buccal side and one from the palatal side (Figure 12d and Table 2).²⁰

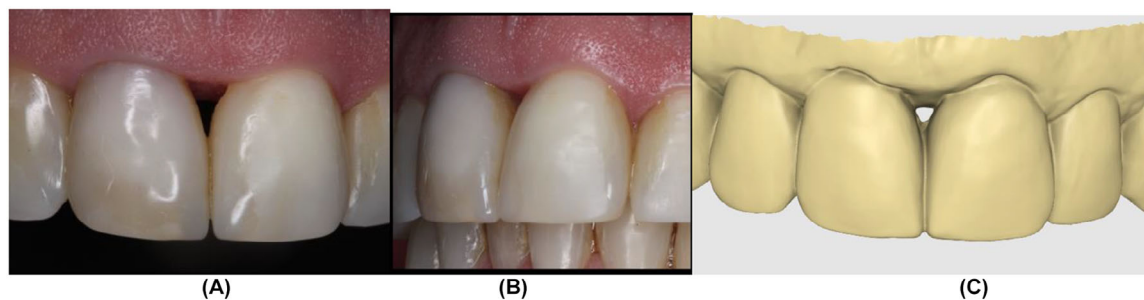


FIGURE 2 Case 1: (a and b) clinical photograph, frontal and lateral view. The patient presents with papilla presence index (PPI) 3 (Cardaropoli classification) in the mesial area of teeth 8 and 9. (c) Intraoral scanner image, frontal view, in Polygon File Format (PLY).



FIGURE 3 Vertex technique description: tunnel preparation. (a) Schematic representation of the mesial aspect of tooth 8 illustrating preoperative conditions. (b) Clinical photograph, frontal view, illustrating the tunnel configuration. A full/partial-thickness vestibular flap was elevated, and the papillae were carefully lifted to allow for the successful displacement of the flap towards the coronal and palatal areas. (c) Schematic representation of the mesial aspect of tooth 8 illustrating the tunnel configuration.

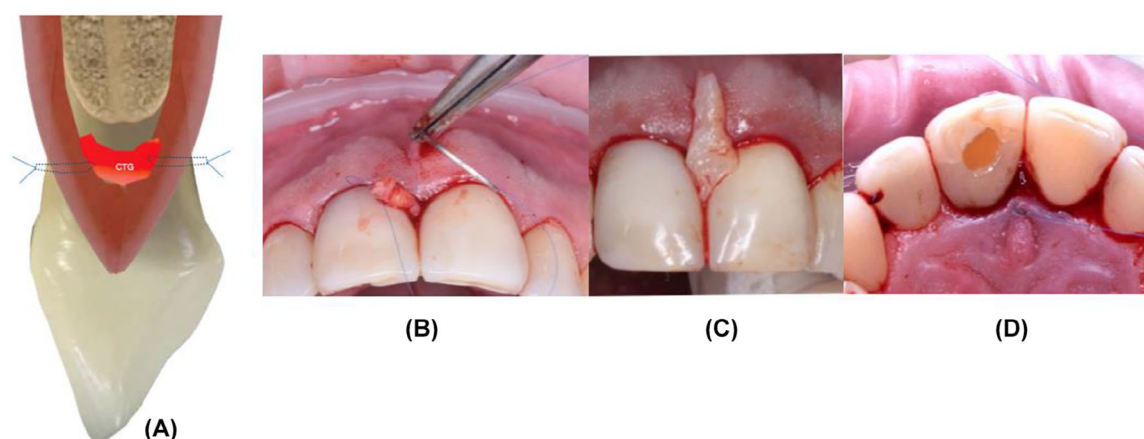


FIGURE 4 Vertex technique description: insertion of the connective tissue graft (CTG). (a) Schematic representation of the mesial aspect of tooth 8 of the insertion of CTG (red). (b–d) Clinical photographs, frontal and palatal view, illustrating the insertion.

RESULTS

Partial papilla reconstruction was achieved. In cases 1 and 2, the papilla height improved from PPI 3 at baseline to PPI 2 after treatment. In case 3, it improved from PPI 4

to PPI 2. Clinical parameters demonstrated no BOP during follow-up, stable PD, and a reduction in the relative vertical height of the papilla, measured as the distance between the contact point and the apex of the interdental papilla, by 1.5 mm in case 1, with a mean of superimposition 3D

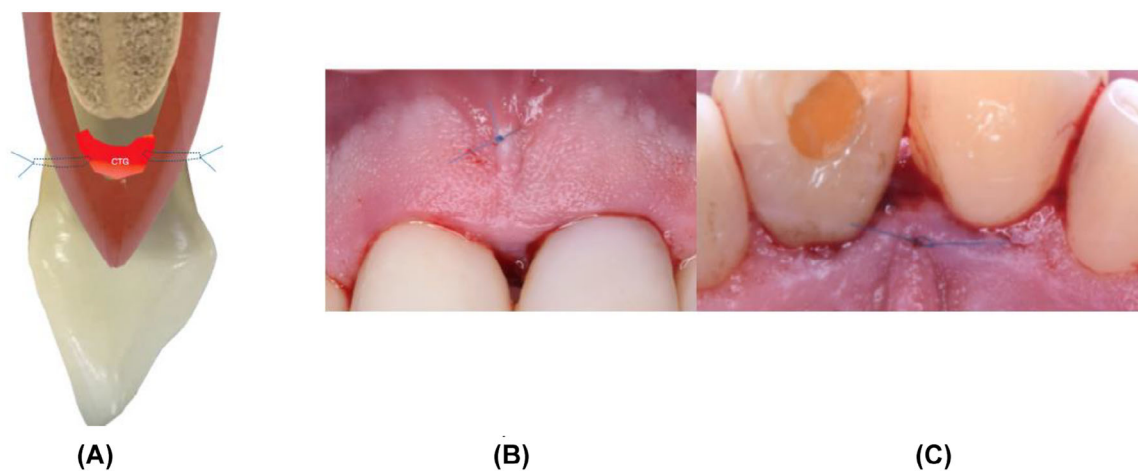


FIGURE 5 Vertex technique description: suturing of the connective tissue graft (CTG). (a) Schematic representation of the mesial aspect of tooth 8 of the suturing of CTG. (b and c) Clinical photographs, frontal and palatal view, illustrating the completed suturing.

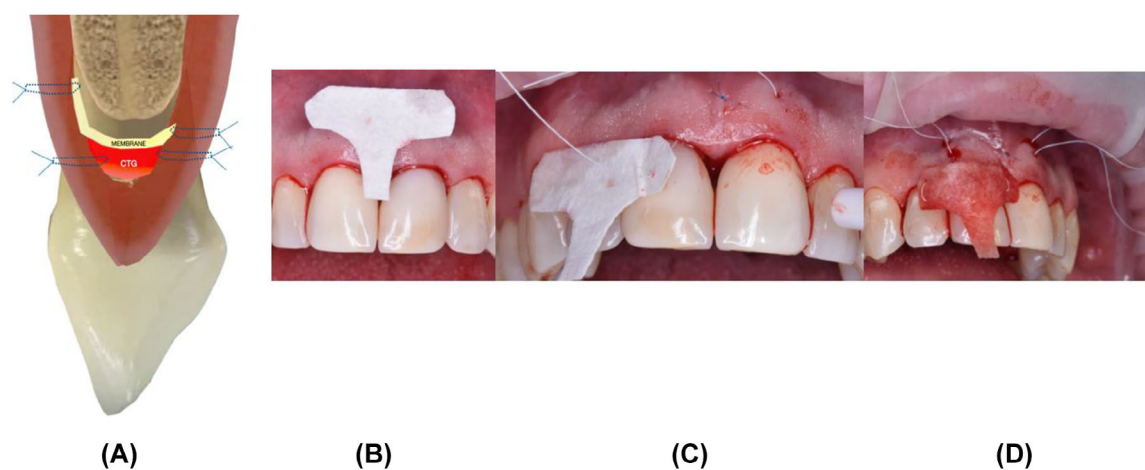


FIGURE 6 Vertex technique description: insertion of the resorbable membrane. (a) Schematic representation of the mesial aspect of tooth 8 of the insertion of the resorbable membrane. (b–d) Clinical photographs, frontal view, illustrating the insertion.

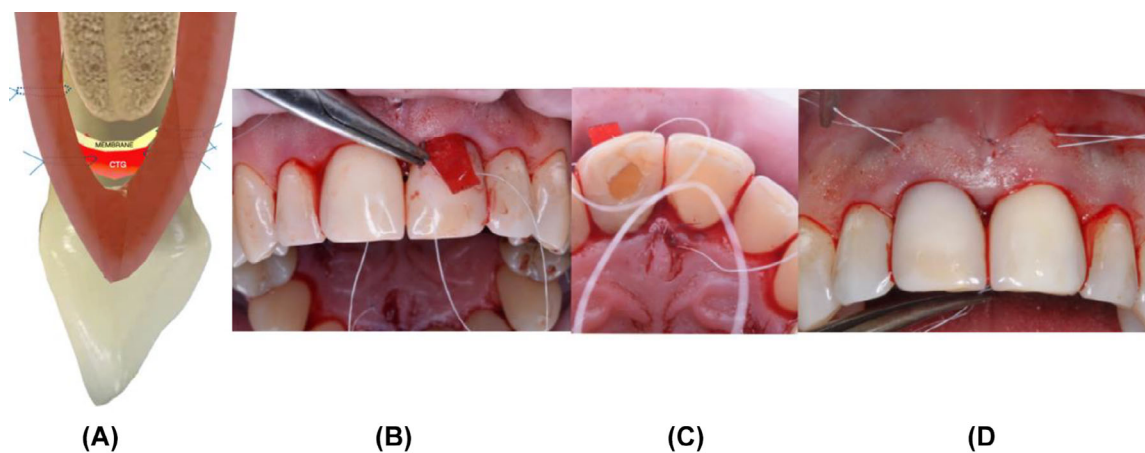


FIGURE 7 Vertex technique description: suturing of the resorbable membrane. (a) Schematic representation of the mesial aspect of tooth 8 of the suturing of the resorbable membrane. (b–d) Clinical photographs, frontal and palatal view, illustrating the suturing.

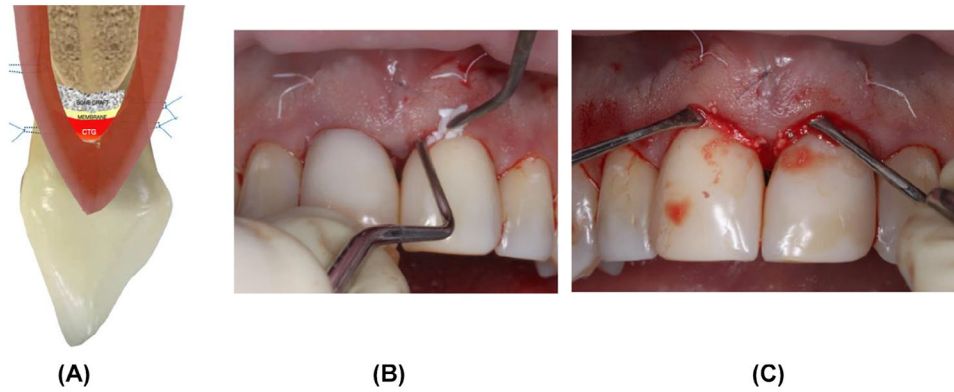


FIGURE 8 Vertex technique description: insertion of the bone graft. (a) Schematic representation of the mesial aspect of tooth 8 of the insertion of the bone graft. (b and c) Clinical photographs, frontal view, illustrating the insertion.

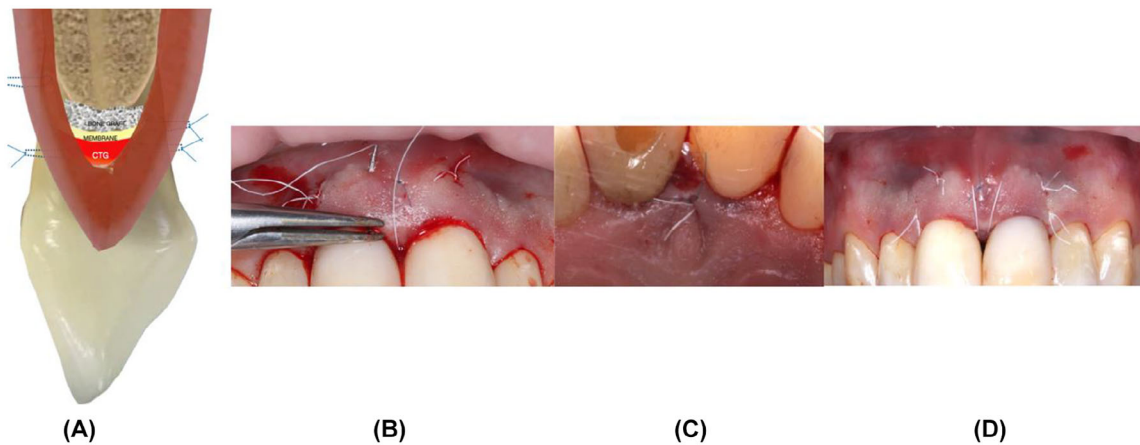


FIGURE 9 Vertex technique description: final suturing of the flap. (a) Schematic representation of the mesial aspect of tooth 8 of the final suturing of the flap. (b–d) Clinical photographs, frontal and palatal view, illustrating the final suturing.

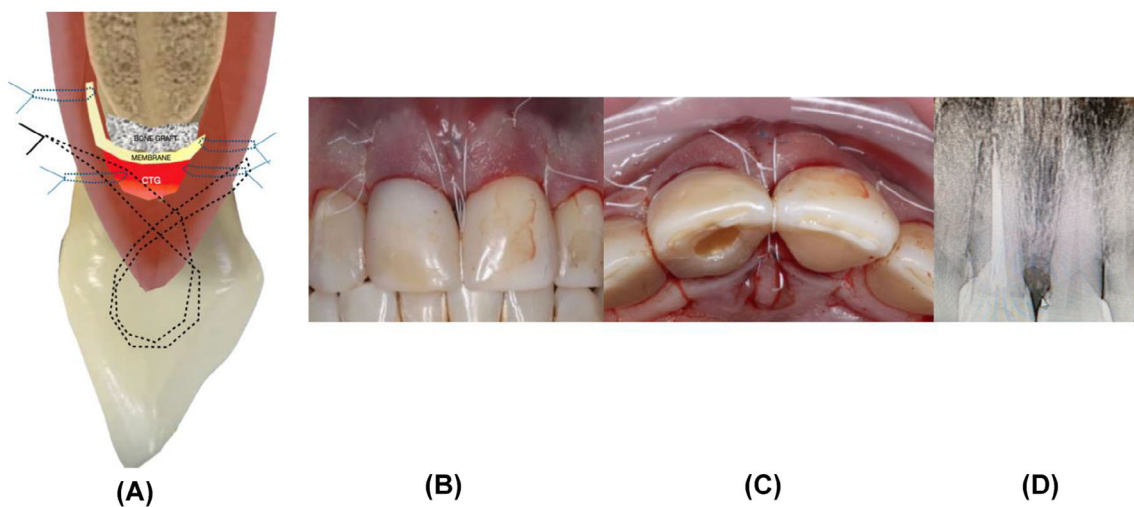


FIGURE 10 Vertex technique description: final suturing with a double-crossed suture. (a) Schematic representation of the mesial aspect of tooth 8 of the final suturing of the flap with a double-crossed suture. (b and c) Clinical photographs, frontal and incisal view, illustrating the suture. (d) Postoperative periapical radiograph of teeth 8 and 9.

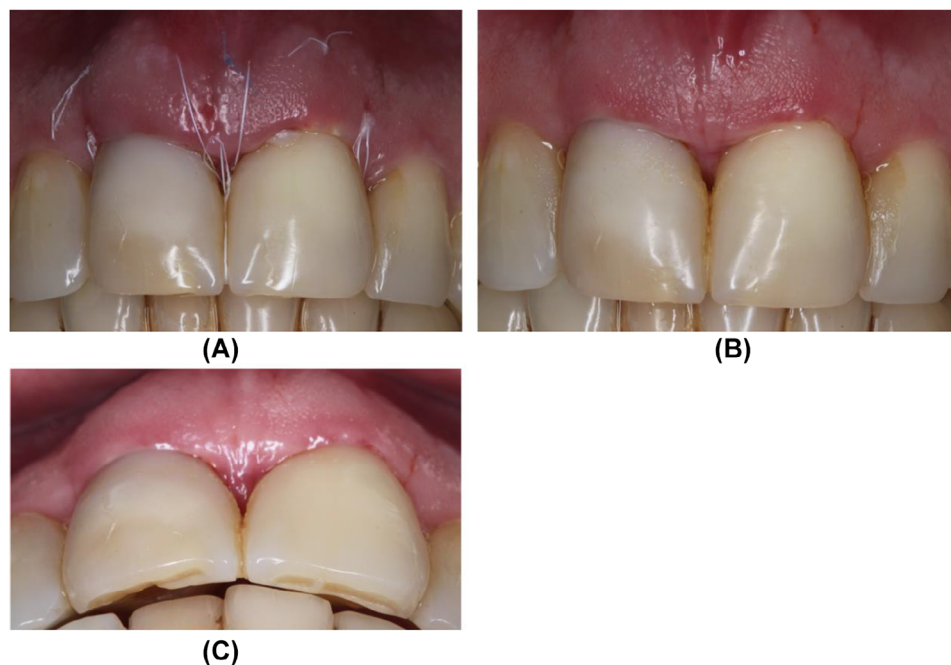


FIGURE 11 Postoperative follow-up. (a) Clinical photograph, frontal view of the 1-week postoperative follow-up. (b) Clinical photograph, frontal view of the 2-week postoperative follow-up and suture removal. (c) Clinical photograph, incisal view of the 2-week postoperative follow-up.

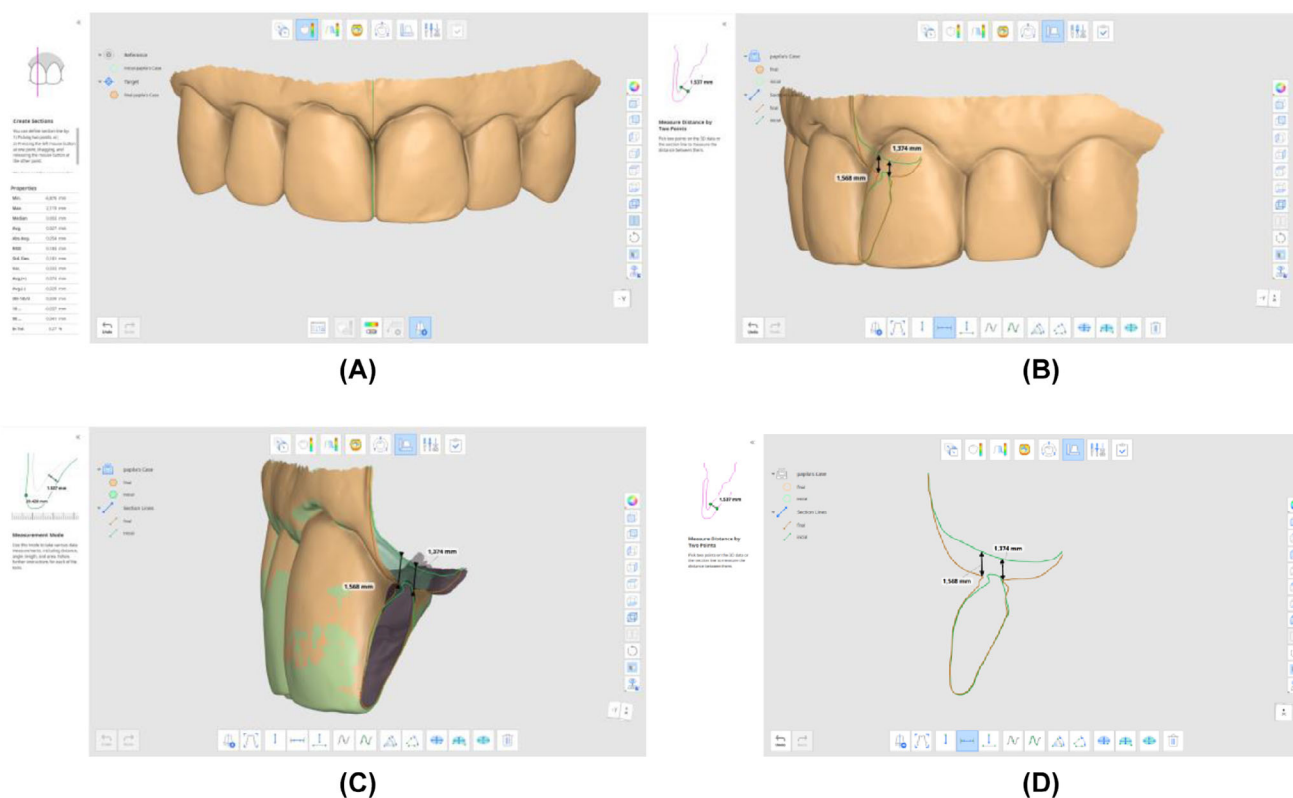


FIGURE 12 Standard Tessellation Language (STL) file acquisition, overlapping and height papilla measurements in image software. (a) Frontal view of the initial and final STL files overlapped and imported into image analysis software for further evaluation. A reference line was drawn to identify the area for measuring changes in the height of the interproximal soft tissue. (b) Selection of the most apical vestibular and palatal points, quantifying the differences in height in millimeters between the initial and final soft tissue positions. (c) Tooth 9 was removed using the software tools to visualize the differences in interproximal soft tissue height. (d) Silhouette of tooth 8 showing the initial (green) and final (light brown) soft tissue contours, and the distances between both outlines.



FIGURE 13 Clinical outcomes. (a) Frontal view of the Polygon File Format (PLY) image from the initial (top) scan and at 6 months postoperative (bottom). (b) Clinical photograph, close-up of the frontal view of the initial situation (top) and at 6 months postoperative (bottom). (c and d) Clinical photograph, frontal view of the initial situation (c) and at 6 months postoperative (d). (e) Clinical photograph, frontal view, 1-year follow-up.

models (SD3) of 1.47 mm. Favorable soft tissue responses were observed over a 1-year follow-up period (Figure 13). On the other hand, cases 2 and 3 were followed up for 2 and 5 years, respectively (Figures 14 and 15). Detailed clinical measurements are provided in Table 2.

Comparison between preoperative and postoperative CBCT scans

In case 3, the initial supra-alveolar bone height was compared with the bone height at the 5-year follow-up. To perform the measurements, Blue Sky software (Blue Sky Plan software version 5.0.19) was used. In the first step,

the CBCT volume was oriented by aligning the occlusal plane parallel to the floor plane in both frontal and lateral views. Subsequently, to establish the location of the sagittal slice passing through the center of the interincisal papilla, a reference point was identified in the occlusal view corresponding to the most anterior projection of the anterior nasal spine, an anatomical structure clearly visible in both tomographic studies. Once the sagittal section was determined in both CBCT scans (one taken before surgery and the other 5 years postoperatively), a line was drawn connecting the lowest point of the palatal aspect of the incisive canal to the most coronal point of the palatal bone ridge, where the greatest change in bone height was observed. This distance was then measured. A vertical gain of 0.71 mm

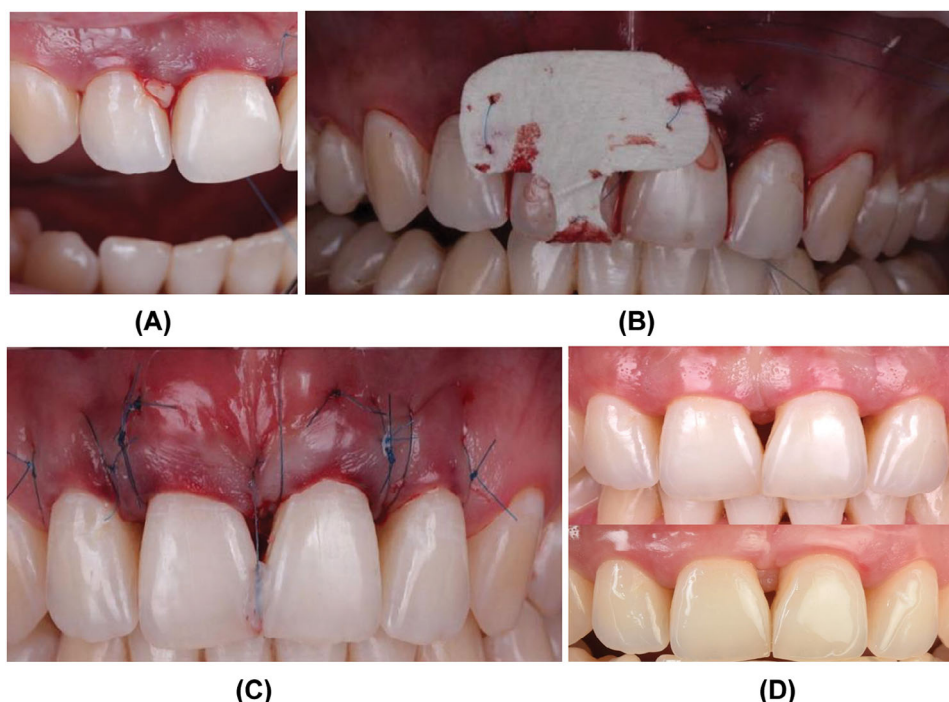


FIGURE 14 Case 2: (a–c) intraoperative photos.(d) Clinical photograph, frontal view of the initial situation (upper) and at 2 years postoperative (bottom).

was observed between the preoperative and postoperative CBCT images (Figure 15g).

DISCUSSION

Partial or complete loss of the interdental papilla is a common complication following both non-surgical and surgical periodontal therapy, resulting from tissue remodeling and attachment loss. Given the high global prevalence of periodontitis, papilla loss is frequently encountered in clinical practice, particularly in advanced cases involving significant destruction of both soft and hard tissues.²¹ This underscores the need for effective reconstructive strategies to restore papillary form and function, ultimately enhancing clinical outcomes and patients' quality of life.¹²

Various surgical and non-surgical techniques have been proposed for the reconstruction of the interdental papilla, including the use of CTG and coronal advanced flaps.^{1,3,7,9,12} However, these strategies face significant limitations, such as low predictability in advanced defects in long-term outcomes and the difficulty in preserving adequate vascularization in a reduced anatomical space. For this reason, the purpose of this case report was to develop a VT capable of correcting both bone and soft tissue defects.

Unlike other techniques, the VT stands out by comprehensively addressing interproximal bone reconstruction, rather than focusing solely on soft tissue replacement with CTG. It involves creating a tunnel in the treatment area, followed by insertion of a CTG, placement of a resorbable

membrane, and containment of particulate bone grafts. The use of the membrane is based on guided tissue regeneration principles, acting as a barrier between the flap and root surface to promote wound healing. It delays epithelial downgrowth, prevents gingival connective tissue from contacting the root, and supports regeneration from periodontal ligament stem cells. Additionally, the membrane stabilizes the bone graft material.^{16,22,23} This approach aims not only at esthetic papilla reconstruction but also at interproximal attachment gain, offering a more complete solution for defects PPI 3–4.

This report presents a VT with long-term follow-up, highlighting its efficacy in defects classified as PPI 3 and 4. The microsurgical approach offers significant advantages to periodontal surgery. First, the use of magnification enhances normal vision, which, when combined with improved lighting, results in greater precision during surgical execution. Its minimally invasive nature and high surgical precision contribute to optimized healing and more predictable results. Compared to macroscopic periodontal surgery, microsurgery provides greater patient comfort, reduced tissue trauma, faster healing, and overall superior clinical outcomes.²⁴ Second, due to the use of microsurgical instruments and microsurgical sutures, there is reduced trauma and better tissue perfusion, which may help maintain the viability of both bone and connective grafts when compared with clinical performance under routine and macroscopic conditions.^{25–29} Other advantages of the VT include reduced postoperative inflammation, as it is a closed technique without surgical edges and primary wound closure for blood clot protection. Most importantly,

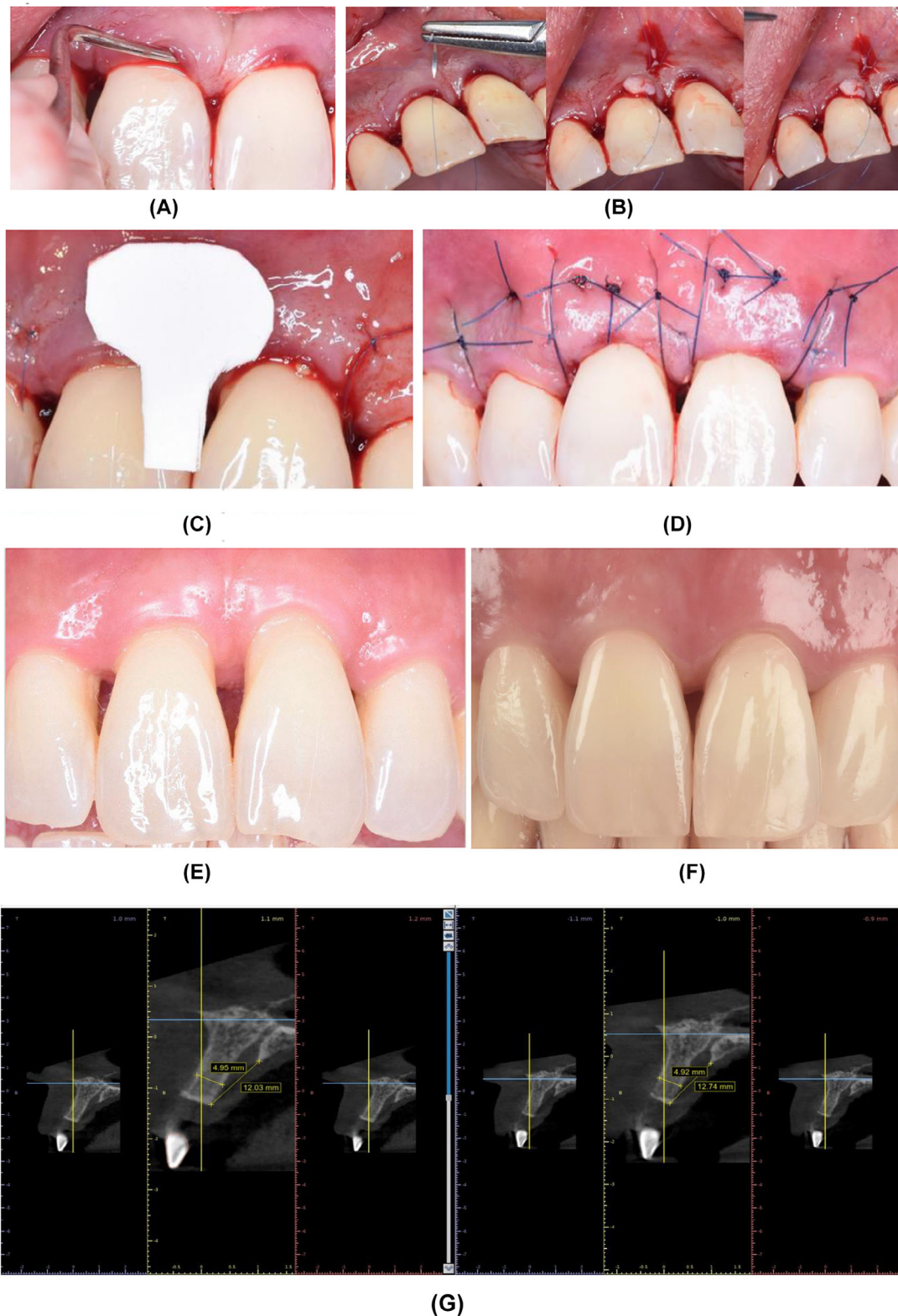


FIGURE 15 Case 3: (a–d) intraoperative photos. (e) Frontal clinical photograph of the initial situation. (f) Frontal clinical photograph at 5-year follow-up. After 3 years postoperatively, a prosthetic intervention consisted of an esthetic adjustment to harmonize the incisal edges of teeth 8 and 9, using composite resin limited solely to the incisal edge. (g) A comparison between preoperative (left) and postoperative (right) cone beam computed tomography (CBCT) scans revealed a gain of 0.71 mm.

the stability of the papillary architecture and interproximal attachment level is achieved in the long term (evaluated over 5 years in case 3 in this study, Table 2), as a scaffold forms from the bone graft that supports the soft tissue.

This technique was performed in patients with a thick phenotype, as they typically present with lower festooning and a wider papillary base compared to those with a thin phenotype.²⁸ This anatomical condition allows for papillae with a reduced risk of surgical tearing and provides greater vascularization than papillae with a narrow base, as occurs with a thin phenotype. Moreover, the high festooning combined with the narrow papillary base characteristic of a thin phenotype is an unfavorable combination, as it does not provide the space or the vascular supply needed to introduce different types of biomaterials and CTGs.³⁰ Additionally, the patients presented with PPI scores of 3 or 4, indicating advanced tissue loss. While esthetic concerns are also present in cases with lower PPI values, such as PPI 2, the technique may not always be indicated. When considering the procedure for PPI 2 cases, it is essential to evaluate the presence of bone tissue loss and determine whether a full procedure, involving both hard and soft tissues, or a soft tissue approach alone should be performed. However, further studies are needed.

During the first 6 weeks, a significant clinical increase in interproximal attachment was observed, as expected due to postsurgical inflammation. This gain slightly decreased by 6 months, followed by a progressive increase in volume and height from the 7th month, stabilizing around 12 months, suggesting a creeping attachment-like phenomenon. This stability persisted throughout the follow-up period (2–5 years). Although creeping attachment has been described in mucogingival surgeries, especially in root coverage procedures, it has not been documented in papilla regeneration. This gap may stem from limited awareness of the phenomenon in this context.³¹

The authors associate this tissue behavior with the use of a membrane, consistent with guided surgery principles. It is hypothesized that creeping attachment is more likely to occur around teeth due to the favorable cellular environment provided by the periosteum and periodontal ligament fibroblasts over exposed root surfaces. Surgical trauma may stimulate cellular activity from the periodontal ligament, periosteum, and gingival tissues, promoting coronal migration of the gingival margin.³¹ However, due to the absence of histological and comprehensive clinical studies, the exact biological origin of this finding remains uncertain.

After performing this technique, partial reconstruction of the interdental papillae was observed, enhancing esthetic outcomes. This improvement was assessed through the PPI, which shifted from values of 4 or 3 to 2, with stable results at both medium-term (1–2 years) and long-term (5 years) follow-ups, suggesting treatment effectiveness and durability. Although there was an increase in papillary height and volume, these results are not directly comparable to

other studies due to the use of different indices in the literature as outcomes for surgical procedures. It is necessary to standardize an index that accurately reflects papilla gain, allowing for consistent evaluation and comparison across different studies and clinical protocols.

Intraoral scanning offers multiple benefits for documenting and evaluating interdental papilla loss. It enables precise, non-invasive 3D imaging for detailed analysis of gingival morphology and accurate detection of interproximal defects. Superimposing digital files enables the objective and reproducible measurement of height and volume changes, improving surgical planning and long-term outcome assessment. For valid comparisons, patients must maintain their periodontal health and avoid new interventions (e.g., restorations or orthodontics) between scans, ensuring changes reflect the technique itself. Although automation reduces operator variability, further validation is needed to confirm measurement accuracy before widespread clinical adoption.³² Once validated, integrating digital data into artificial intelligence models may improve diagnosis, guide timely decisions, and enhance patient care.

Despite its advantages, the VT has certain limitations. First, in all three cases, the surgeries were performed by skilled operators. It is reasonable to assume that the clinician's technical expertise contributed to the successful outcome, as the procedure demands advanced skills to operate within a confined space and under closed-field conditions. Additionally, compared to conventional tunneling techniques using CTG, the procedure involves higher costs and clinical time due to the use of multiple grafts and membranes, as well as the need for a surgical microscope, magnification loupes, and a high-precision microsurgical suturing technique. These limitations could restrict its implementation in clinical settings with limited resources, underscoring the need for specialized training and cost optimization.

Future research should include controlled clinical trials with larger sample sizes and follow-up periods of at least 12 months to evaluate the reproducibility and long-term stability of this technique. STL analysis for height and volume measurements should ideally be included, specifically to evaluate changes in papilla height between the initial and final stages. Additionally, exploring the impact of different types of bone grafts and membranes on interdental papilla reconstruction would be of interest.

CONCLUSION

The VT represents a significant improvement in the reconstruction of the interdental papilla by combining microsurgical principles with bone and CTGs. This innovative approach has proven to be an effective and predictable alternative for periodontally treated patients with papilla defects PPI 3 and 4 and thick phenotype, contributing to reduced interproximal clinical attachment loss and enhanced dental esthetics.

AUTHOR CONTRIBUTIONS

Fernando Solanes contributed substantially to conception, planning, and performance of the surgical technique. Juan Carlos Durán contributed substantially to the planning and execution of the surgical technique, study conception and design, original draft preparation, and critical review and editing of this manuscript. Valeria Gómez contributed substantially to study conception and design, conceptualization, original draft preparation, and critical review and editing of this manuscript. Carolina Alarcón, María Dolores de la Jara, and Cristian Aguilera contributed substantially to original draft preparation, and critical review and editing of this manuscript. All authors gave their final approval and agreed to be accountable for all aspects of the work.

ACKNOWLEDGMENTS

The authors would like to thank Dr. María Ignacia Vallejo for her contributions in the translating and editing of this manuscript.

CONFLICT OF INTEREST STATEMENT

The authors do not have any financial interest in the products and technologies described in this article. The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

INFORMED CONSENT

The patients signed written consents.

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How to cite this article: Solanes F, Durán JC, Alarcón C, de la Jara MD, Gómez V, Aguilera C. Vertex technique: A novel microsurgical technique for papilla reconstruction—Case study. *Clin Adv Periodontics*. 2026;1-15.
<https://doi.org/10.1002/cap.70028>