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An evidence-based digital workflow for palatal soft tissue graft harvesting: technique description and case report

Kubra Burcu Yildirim

kb3387@mynsu.nova.edu

Nova Southeastern University

Deniz Findik Balci

Private Periodontology Practice

ERTUGRUL YILDIRIM

KEM Dental Clinic

Sinem Tuna

Private Periodontology Practice

Case Report

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Authors

Kubra Burcu Yildirim, DDS, PhD[1] ORCID: 0000-0001-6309-1008

Deniz Findik Balci, DDS, PhD[2] ORCID: 0009-0008-5637-8842

Ertugrul Yildirim, CDT[3] ORCID: 0009-0005-3324-4751

Sinem Tuna, DDS, PhD[2] ORCID: 0009-0008-0620-7391

Affiliations

[1] Advanced Education in General Dentistry Program, Nova Southeastern University College of Dental Medicine, 3200 South University Drive, Fort Lauderdale, FL 33328, USA

[2] Private Periodontology Practice, Istanbul, Turkey

[3] KEM Dental Clinic, Istanbul, Turkey

Corresponding author

Kubra Burcu Yildirim, DDS, PhD

Advanced Education in General Dentistry Program

Nova Southeastern University College of Dental Medicine

3200 South University Drive, Fort Lauderdale, FL 33328, USA

Email: kb3387@mynsu.nova.edu

Abstract

Purpose To describe a digital workflow in which published greater palatine artery (GPA) safety zone values are mapped onto a patient's palatal model using an open-source software tool, enabling chairside fabrication of a printed harvesting guide without cone-beam computed tomography (CBCT).

Methods A full-arch maxillary intraoral scan was imported into a dedicated software tool compatible with 3Shape Dental Designer and Exocad. After the clinician marked palatal cervical landmarks, the software computed a harvesting window from the tooth-specific weighted mean CEJ-to-GPA distances reported by Tavelli et al., adjusted by one standard deviation and a 2 mm gingival margin offset. The geometry was exported as an STL file, integrated into a guide design, and fabricated by digital light processing. The workflow is illustrated through connective tissue graft harvesting for tunnel technique root coverage at tooth 23.

Results The printed guide seated passively without adjustment. Harvesting incisions were performed within the planned boundaries with the blade maintained in contact with the guide borders. The GPA was not encountered and no bleeding complications occurred. Palatal healing was uneventful at 7 and 14 days.

Conclusion This workflow offers a radiation-free, reproducible means of transferring population-level evidence into the surgical field. It does not localize the artery per patient but may provide a more systematic alternative to manual estimation.

Clinical relevance Per-patient vascular imaging is rarely justified for routine harvesting, and ultrasound and dedicated MRI are unavailable in most practices. This workflow applies existing evidence systematically using only a routine intraoral scan and a desktop printer, making it applicable in everyday clinical settings.

Keywords Computer-guided surgery · Connective tissue graft · Digital workflow · Gingival recession · Palatine artery · Surgical guides

Introduction

Palatal soft tissue graft harvesting is among the most commonly performed procedures in periodontal plastic surgery, yet it carries a risk that experienced clinicians continue to encounter: inadvertent injury to the greater palatine artery (GPA). When this happens, the consequences extend beyond bleeding control — operative time is lost, the surgical field is compromised, and the graft itself may be affected [1–3]. For a procedure that is otherwise predictable, this single anatomical variable introduces an element of uncertainty that is difficult to eliminate through skill alone [4].

The anatomy behind this risk is well documented. A systematic review by Tavelli et al. [5], analyzing 5,768 hemipalates across cadaveric and CBCT studies, established tooth-specific distances between the GPA and the cementoenamel junction (CEJ): 9.9 ± 2.9 mm at the canine, 11.8 ± 2.2 mm at the first premolar, 13.8 ± 2.1 mm at the second premolar, 13.0 ± 2.4 mm at the first molar, and 13.9 ± 1.0 mm at the second molar. Applying these values, the safe harvesting depth works out to 5.0, 7.6, 9.7, 8.7, and 10.9 mm from the gingival margin at the canine, first premolar, second premolar, first molar, and second molar regions, respectively. The data are robust. The problem is not the evidence — it is getting that evidence reliably into the operating field. Fu et al. [6] showed that even trained examiners underestimate the greater palatine foramen location by up to 4 mm when relying on

clinical palpation and estimation, which means the safety zone, however well defined on paper, remains operator-dependent in practice [7] (Fig. 1).

The imaging modalities capable of resolving this uncertainty are, in practice, unavailable. CBCT can map the GPA directly on a per-patient basis, but ordering a CBCT solely to guide a harvesting procedure is difficult to justify — the diagnostic yield does not warrant the radiation exposure, and the ALARA principle applies. Ultrasound and MRI have been proposed as radiation-free alternatives [8, 9], but neither is available in the routine periodontal setting: intraoral ultrasound remains confined to research centres, and dedicated dental MRI protocols exist in only a handful of institutions worldwide. The everyday reality is therefore a clinician working from memory of published means, with no practical route to individualized vascular assessment.

Digital planning, by contrast, has already entered routine periodontal practice [10, 11]. Santamaria et al. [12, 13] recently demonstrated that three-dimensional printed guides designed from intraoral scans can standardize incision placement for coronally advanced flap procedures and graft harvesting, reducing reliance on intraoperative judgment. Their palatal harvesting guide, however, used a fixed 2 mm offset from the gingival margin as the coronal boundary — a practical simplification, but one that does not reflect the tooth-specific anatomical variation documented by Tavelli et al. [5], particularly in the canine region where the safety margin narrows considerably.

The technique described here attempts to close that gap using tools that are already present in many practices. Using a dedicated open-source software tool, the safety zone values from Tavelli et al. [5] are mapped directly onto the patient's digital palatal model, generating a harvesting window that reflects the population-level anatomical risk for each tooth region. The guide is printed chairside and used intraoperatively to define incision limits before harvesting begins — without CBCT, without manual measurement at the chair, and with the goal of applying evidence-based boundaries systematically rather than relying on estimation. It is not presented as a guarantee of arterial safety, but as a means of bringing the best available evidence into the surgical field under the constraints of ordinary clinical practice. The workflow is illustrated through a clinical case involving a connective tissue graft harvested for tunnel technique root coverage at tooth 23 [14–16].

Case report

This manuscript describes a digital workflow for evidence-guided palatal soft tissue graft harvesting, illustrated by a representative clinical case. As this constitutes a technique description with an illustrative case component, the clinical case data are reported in accordance with the CARE (CAse REport) guidelines [17].

A 26-year-old systemically healthy female patient presented with a type 1 gingival recession (RT1) [18] at tooth 23 (maxillary left canine, FDI) with a recession depth of 3 mm and a keratinized tissue width of 2.5 mm. Gingival thickness was measured at 1.3 mm. The patient reported a history of orthodontic treatment. Additional baseline clinical parameters including probing depth, bleeding on probing, and visible plaque index were recorded. The patient provided written informed consent prior to treatment. All procedures were performed under private practice conditions.

Digital workflow and surgical guide fabrication

A full-arch maxillary intraoral scan was obtained using a TRIOS 3 intraoral scanner (3Shape A/S, Copenhagen, Denmark) and exported in polygon file format (PLY). A dedicated open-source software tool [19] developed specifically for this workflow was used to map evidence-based GPA safety zone boundaries onto the patient's digital palatal model. The tool accepts intraoral scan files (STL/PLY) as input; the clinician identifies the palatal cervical margins of the reference teeth by placing landmark points directly on the three-dimensional model, after which the software automatically calculates and renders a three-dimensional harvesting window based on the tooth-specific weighted mean CEJ-to-GPA distances reported by Tavelli et al. [5], adjusted by one standard deviation and an additional 2 mm offset to account for the physiologic gingival margin position: canine region, 5.0 mm; first premolar region, 7.6 mm; second premolar region, 9.7 mm; first molar region, 8.7 mm; second molar region, 10.9 mm. The coronal harvesting limit was positioned 2 mm apical to the palatal gingival margin of the reference teeth (Fig. 2). The resulting harvesting window was exported as an STL file and imported into 3Shape Dental Designer (3Shape A/S) for surgical guide design; the complete digital workflow is illustrated stepwise in Fig. 3 (a–e). The guide was fabricated using an Asiga MAX 2 digital light processing (DLP) printer (Asiga, Alexandria, NSW, Australia) with Asiga DentaGUIDE biocompatible resin, following the manufacturer's washing and post-curing specifications. Passive fit of the printed guide was verified on a three-dimensional printed study model prior to intraoral use (Fig. 4a–b).

Use of AI tools: Artificial intelligence-assisted writing tools (Claude, Anthropic) were used to assist in the preparation of this manuscript. All AI-generated content was reviewed, edited, and verified by the authors, who take full responsibility for the accuracy, integrity, and originality of the submitted work. No AI tool was used in the development of the software, the clinical procedure, or the analysis of clinical data.

Surgical procedure

All surgical procedures were performed under local anesthesia with 4% articaine with epinephrine 1:100,000. The recipient site preparation at tooth 23 was performed using the tunnel technique [14–16]. A full-thickness tunnel was extended to the adjacent teeth (22 and 24) both mesially and distally to the recession defect, ensuring adequate graft accommodation without tension [20].

For the donor site, the fabricated palatal harvesting guide was seated on the maxillary arch and verified for passive fit and stability prior to incision (Fig. 4c). Using a no. 15c scalpel blade (Swann Morton, Sheffield, UK) held perpendicular to the mucosal surface and in close contact with the guide borders, the harvesting incisions were performed (Fig. 5a). The guide was subsequently removed and the graft was harvested and de-epithelialized with the same blade to obtain a pure connective tissue specimen measuring approximately 15 × 5 × 1.5 mm, preserving the most superficial connective tissue layer as described by Zucchelli et al. [21] (Fig. 5b). The graft was introduced into the prepared tunnel using a suture pull-through technique with a 4-0 polyglactin suture (Pegelag Rapid; Dogsan, Trabzon, Turkey) and advanced to fully cover the recession defect at tooth 23. Graft stabilization was achieved with 5-0 polypropylene sutures (Dogsan). The palatal donor site was left to heal by secondary intention (Fig. 5c).

Postoperative care included ibuprofen 600 mg and chemical plaque control with 0.12% chlorhexidine gluconate mouth rinse twice daily for 14 days. Sutures at the donor site were removed at 14 days postoperatively.

Clinical outcomes

The printed guide seated passively on the maxillary arch without adjustment, and its borders remained stable throughout the procedure. Harvesting incisions were performed with the scalpel blade maintained in continuous contact with the guide borders.

Intraoperative bleeding was negligible. The greater palatine artery was not encountered, and no hemostatic measures beyond routine gauze pressure were required. This allowed the procedure to progress without interruption.

The harvested connective tissue graft measured 15 × 5 × 1.5 mm and showed satisfactory tissue quality following de-epithelialization. The graft dimensions corresponded to the harvesting window defined by the digital guide, confirming accurate transfer of the planned geometry to the surgical field. The graft was introduced into the prepared full-thickness tunnel extending from tooth 22 to tooth 24 and stabilized without tension.

Baseline clinical presentation of the recession defect at tooth 23, tunnel preparation, immediate postoperative appearance following graft stabilization, and 7-day follow-up are presented in Fig. 6 (a–e). Initial soft tissue coverage was observed at 7 days, with no signs of graft exposure or necrosis; early revascularization of the connective tissue graft was clinically evident.

The donor site was left to heal by secondary intention. No postoperative bleeding was reported. At 7 and 14 days postoperatively, the donor site showed uneventful healing with progressive tissue repair and no signs of dehiscence or infection (Fig. 7). The patient reported minimal postoperative discomfort and did not require analgesic use beyond the prescribed protocol.

Patient perspective

I was informed that I had a gum recession at one of my upper teeth and that this could be treated with a graft procedure using tissue from the roof of my mouth. My surgeon explained that a custom-made guide would be used during the procedure to plan the harvesting site more precisely and to avoid the blood vessels in that area. I consented to the treatment and agreed to have my anonymized clinical data used for research purposes.

Discussion

Translating anatomical knowledge into intraoperative precision has long been a challenge in palatal soft tissue graft harvesting [3–5]. The safety zone values published by Tavelli et al. [5] are well supported — derived from nearly 6,000 hemipalates across cadaveric and imaging studies — yet their clinical application has remained largely manual and operator-dependent. The technique described here represents one approach to narrowing that gap: by encoding published safety zone values into a digital guide informed by population-level anatomical data, the harvesting window can be defined during preoperative planning rather than estimated at the chair.

The guided harvesting approach introduced by Santamaria et al. [12, 13] represented an important step in this direction, demonstrating that digitally designed palatal guides are feasible and can assist in delimiting the graft area. Their palatal boundary, however, was set at a uniform 2 mm apical to the gingival margin across all posterior teeth — a practical simplification, but one that does not reflect the tooth-specific variation in GPA proximity documented in the literature [5, 7, 22, 23]. The difference is not trivial. At the second premolar, a 2 mm offset and a Tavelli-derived safety zone of 9.7 mm are not in conflict. At the canine, they are: the evidence-based limit is 5

mm from the gingival margin, and a fixed 2 mm offset provides no guidance on how far apically harvesting can safely extend in that region. The present workflow addresses this by encoding the tooth-specific safety zone values directly into the software tool, so that each region of the harvesting window reflects the anatomical risk at that location rather than a single uniform assumption. Beyond anatomical precision, this workflow offers a fully documented, step-by-step digital protocol — from landmark identification and safety zone computation to guide design and fabrication — that can be reproduced by any clinician with access to an intraoral scanner and a DLP printer, without reliance on operator-specific estimation.

The canine region deserves particular attention in this context. With a weighted mean GPA-to-CEJ distance of only 9.9 mm and a standard deviation of 2.9 mm — the widest relative variability of any posterior tooth — the calculated safety zone narrows to 5.0 mm from the gingival margin [5]. The GPA also tends to run closer to the alveolar crest in this region [6, 22, 23], and this is precisely where intraoperative estimation is least reliable and where a guide derived from population-level anatomical data adds the most value.

Several limitations of this technique warrant explicit discussion. First, the safety zone formula proposed by Tavelli et al. [5] was derived from subjects with normal palatal anatomy, and the current workflow does not account for morphological variation in palatal vault depth. Reiser et al. [4] described shallow, average, and deep vault configurations, each associated with different tissue thicknesses and vascular proximity. In shallow vaults, where the GPA runs closer to the mucosal surface, the margins provided by population-level data may be less conservative than assumed. Future iterations of the workflow should consider integrating vault classification as an additional parameter. Second, while the guide defines the coronal, apical, and lateral boundaries of the harvesting window in two dimensions, it does not control incision depth — graft thickness remains entirely at the clinician's discretion, as it does with all current harvesting approaches including that of Santamaria et al. [12, 13, 24, 25]. Blade angulation and depth are operator-dependent variables that no current guide technology addresses, and GPA injury risk is not solely a two-dimensional boundary problem. Third, the safety zone formula was derived from periodontally healthy subjects with an assumed 2 mm distance between the CEJ and the gingival margin. In patients with palatal attachment loss or gingival recession on the palatal aspect, these values may not hold, and alternative landmarks — the greater palatine crest, midsagittal suture, or posterior border of the hard palate — should be used to supplement clinical judgment [5, 26]. Fourth, the four GPA branching patterns described by Yu et al. [27] introduce anatomical variability that population-based safety zone values cannot fully capture on an individual level. In type III and IV patterns, the artery runs in closer proximity to the CEJ than the weighted means would suggest, and the current guide offers no protection against these variants without patient-specific vascular imaging [8, 9]. That said, type I — in which the GPA follows the most lateral and predictable course — represents the most commonly encountered pattern in the literature [27]. Finally, the evidence presented here is limited to a single case, and prospective studies with larger samples are needed before any conclusions can be drawn about the clinical impact of this approach on complication rates.

It should be emphasized that this guide does not replace individual vascular assessment and does not guarantee arterial safety; it systematically applies the best available population-level evidence where per-patient imaging is not justified or available. This distinction matters because the alternative in daily practice is not CBCT, ultrasound, or MRI — modalities that, despite their theoretical advantage, remain impractical or inaccessible in routine clinical settings [8, 9] — but unaided mental approximation. Measured against that comparator rather than against an

idealized imaging protocol, remaining within an evidence-based safety zone derived from a large pooled sample may represent a more defensible starting point for the majority of patients.

Where this guide may prove most useful is not necessarily in experienced hands — it is in training. The canine region, where the safety margin is narrowest and the consequences of misjudgment most significant, is also where trainees are most likely to encounter difficulty [5, 6]. A guide that makes the safe harvesting area explicit — rather than leaving it to be estimated — could serve as both a clinical tool and a teaching aid, reducing the learning curve associated with palatal harvesting in anatomically demanding sites [12, 13]. Prospective studies comparing guided and freehand harvesting across operators of varying experience levels would be a logical next step.

Conclusion

This report describes a digital workflow that applies published palatal safety zone data to generate a harvesting guide without preoperative CBCT, using equipment already available in many contemporary practices. The guide systematically encodes population-level anatomical evidence into the harvesting geometry but does not localize the artery on a per-patient basis. Prospective validation studies, including comparison with Doppler ultrasonographic assessment, are needed to evaluate the accuracy and broader clinical impact of this approach.

Statements and declarations

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Competing interests The authors have no relevant financial or non-financial interests to disclose.

Author contributions K.B.Y.: conceptualization, digital workflow design, software implementation, manuscript writing. D.F.B.: conceptualization, surgical procedure, patient follow-up, manuscript review. E.Y.: software development, guide fabrication and additive manufacturing. S.T.: surgical assistance, manuscript review. All authors read and approved the final manuscript.

Ethical approval Not required, since the procedure was performed under private practice conditions as part of routine clinical care.

Consent to participate Written informed consent was obtained from the patient.

Consent to publish The patient provided written informed consent for the publication of her anonymized clinical data and images.

Clinical trial number: not applicable.

Data availability The clinical data supporting this report are available from the corresponding author upon reasonable request. The software described is openly available (see reference 19).

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References

1. Brasher WJ, Rees TD, Boyce WA (1975) Complications of free grafts of masticatory mucosa. J Periodontol 46:133–138. https://doi.org/10.1902/jop.1975.46.3.133

2. Harris RJ, Miller R, Miller LH, Harris C (2005) Complications with surgical procedures utilizing connective tissue grafts: a follow-up of 500 consecutively treated cases. Int J Periodontics Restorative Dent 25:449–459

3. Tavelli L, Barootchi S, Stefanini M, Zucchelli G, Giannobile WV, Wang HL (2023) Wound healing dynamics, morbidity, and complications of palatal soft-tissue harvesting. Periodontol 2000 92:90–119. https://doi.org/10.1111/prd.12466

4. Reiser GM, Bruno JF, Mahan PE, Larkin LH (1996) The subepithelial connective tissue graft palatal donor site: anatomic considerations for surgeons. Int J Periodontics Restorative Dent 16:130–137

5. Tavelli L, Barootchi S, Ravidà A, Oh TJ, Wang HL (2019) What is the safety zone for palatal soft tissue graft harvesting based on the locations of the greater palatine artery and foramen? A systematic review. J Oral Maxillofac Surg 77:271.e1–271.e9. https://doi.org/10.1016/j.joms.2018.10.002

6. Fu JH, Hasso DG, Yeh CY, Leong DJM, Chan HL, Wang HL (2011) The accuracy of identifying the greater palatine neurovascular bundle: a cadaver study. J Periodontol 82:1000–1006. https://doi.org/10.1902/jop.2011.100619

7. Monnet-Corti V, Santini A, Glise JM, Fouque-Deruelle C, Dillier FL, Liébart MF, Borghetti A (2006) Connective tissue graft for gingival recession treatment: assessment of the maximum graft dimensions at the palatal vault as a donor site. J Periodontol 77:899–902. https://doi.org/10.1902/jop.2006.050047

8. Chan HL, Wang HL, Fowlkes JB, Giannobile WV, Kripfgans OD (2017) Non-ionizing real-time ultrasonography in implant and oral surgery: a feasibility study. Clin Oral Implants Res 28:341–347. https://doi.org/10.1111/clr.12805

9. Hilgenfeld T, Kästel T, Heil A, Rammelsberg P, Heiland S, Bendszus M et al (2018) High-resolution dental magnetic resonance imaging for planning palatal graft surgery—a clinical pilot study. J Clin Periodontol 45:462–470. https://doi.org/10.1111/jcpe.12870

10. D'haese J, Ackhurst J, Wismeijer D, De Bruyn H, Tahmaseb A (2017) Current state of the art of computer-guided implant surgery. Periodontol 2000 73:121–133. https://doi.org/10.1111/prd.12175

11. Carrera TMI, Freire AEN, de Oliveira GJPL, dos Reis Nicolau S, Pichotano EC, Ribeiro Junior NV et al (2023) Digital planning and guided dual technique in esthetic crown lengthening: a randomized controlled clinical trial. Clin Oral Investig 27:1589–1603. https://doi.org/10.1007/s00784-022-04780-8

12. Santamaria MP, Ferreira Bonafé AC, Rossato A, Viana Miguel MM, da Costa AP, Mathias-Santamaria IF et al (2025) Guided-modified coronally advanced flap: novel digital approach to treat multiple gingival recessions. Workflow and case study. Clin Adv Periodontics. https://doi.org/10.1002/cap.10362

13. Santamaria MP, Rossato A, Miguel MMV, Mathias-Santamaria IF, Nunes MP, Queiroz LA (2025) Guided coronally advanced flap to treat gingival recession: digital workflow and case report. Clin Adv Periodontics 15:7–13. https://doi.org/10.1002/cap.10282

14. Allen AL (1994) Use of the supraperiosteal envelope in soft tissue grafting for root coverage. I. Rationale and technique. Int J Periodontics Restorative Dent 14:216–227

15. Zuhr O, Bäumer D, Hürzeler M (2014) The addition of soft tissue replacement grafts in plastic periodontal and implant surgery: critical elements in design and execution. J Clin Periodontol 41:S123–S142. https://doi.org/10.1111/jcpe.12185

16. Tavelli L, Barootchi S, Nguyen TVN, Tattan M, Ravidà A, Wang HL (2018) Efficacy of tunnel technique in the treatment of localized and multiple gingival recessions: a systematic review and meta-analysis. J Periodontol 89:1075–1090. https://doi.org/10.1002/JPER.18-0066

17. Gagnier JJ, Kienle G, Altman DG, Moher D, Sox H, Riley D (2014) The CARE guidelines: consensus-based clinical case report guideline development. J Clin Epidemiol 67:46–51. https://doi.org/10.1016/j.jclinepi.2013.08.003

18. Cairo F, Nieri M, Cincinelli S, Mervelt J, Pagliaro U (2011) The interproximal clinical attachment level to classify gingival recessions and predict root coverage outcomes: an explorative and reliability study. J Clin Periodontol 38:661–666. https://doi.org/10.1111/j.1600-051X.2011.01732.x

19. Burcu Yildirim K, Yildirim E (2026) PalGuide. Zenodo. https://doi.org/10.5281/zenodo.19545400

20. Zucchelli G, Mounssif I (2015) Periodontal plastic surgery. Periodontol 2000 68:333–368. https://doi.org/10.1111/prd.12059

21. Zucchelli G, Mele M, Stefanini M, Mazzotti C, Marzadori M, Montebugnoli L et al (2010) Patient morbidity and root coverage outcome after subepithelial connective tissue and de-epithelialized grafts: a comparative randomized-controlled clinical trial. J Clin Periodontol 37:728–738. https://doi.org/10.1111/j.1600-051X.2010.01550.x

22. Klosek SK, Rungruang T (2009) Anatomical study of the greater palatine artery and related structures of the palatal vault: considerations for palate as the subepithelial connective tissue graft. Surg Radiol Anat 31:245–250. https://doi.org/10.1007/s00276-008-0432-4

23. Kim DH, Won SY, Bae JH, Jung UW, Park DS, Kim HJ, Hu KS (2014) Topography of the greater palatine artery and the palatal vault for various types of periodontal plastic surgery. Clin Anat 27:578–584. https://doi.org/10.1002/ca.22252

24. Studer SP, Allen EP, Rees TC, Kouba A (1997) The thickness of masticatory mucosa in the human hard palate and tuberosity as potential donor sites for ridge augmentation procedures. J Periodontol 68:145–151. https://doi.org/10.1902/jop.1997.68.2.145

25. Wara-aswapati N, Pitiphat W, Chandrapho N, Rattanayatikul C, Karimbux N (2001) Thickness of palatal masticatory mucosa associated with age. J Periodontol 72:1407–1412. https://doi.org/10.1902/jop.2001.72.10.1407

26. Benninger B, Andrews K, Carter W (2012) Clinical measurements of hard palate and implications for subepithelial connective tissue grafts with suggestions for palatal nomenclature. J Oral Maxillofac Surg 70:149–153. https://doi.org/10.1016/j.joms.2011.03.066

27. Yu SK, Lee MH, Park BS, Jeon YH, Chung YY, Kim HJ (2014) Topographical relationship of the greater palatine artery and the palatal spine. Significance for periodontal surgery. J Clin Periodontol 41:908–913. https://doi.org/10.1111/jcpe.12288

Figure legends

Fig. 1 Schematic illustration of the greater palatine artery (GPA) course along the palatal vault, depicting tooth-specific distances between the GPA and the cementoenamel junction (CEJ) of the maxillary teeth and the corresponding evidence-based safety zone boundaries as defined by Tavelli et al

Fig. 2 Illustrative three-dimensional rendering of the palatal model depicting the estimated greater palatine artery (GPA) trajectory and tooth-specific evidence-based safety zone distances from the gingival margin at each reference tooth region

Fig. 3 Digital workflow for palatal harvesting guide fabrication. (a) Harvesting planning tool interface displaying the computed safe zone boundaries mapped onto the patient's digital palatal model; coronal limit set at 2 mm apical to the palatal gingival margin and apical limit derived from tooth-specific safety zone values. (b) Safe zone

geometry exported as STL and visualized as an overlay on the palatal scan in the 3D viewer, confirming spatial correspondence prior to guide design. (c) Guide body design in 3Shape Dental Designer, with the harvesting window aperture positioned within the planned safe zone boundaries; occlusal stops and tissue-contacting surface are visible. (d) Three-dimensional render of the finalized surgical guide, confirming harvesting window dimensions and guide body contour prior to fabrication. (e) Intraoral photograph with illustrative overlay of the surgical guide, depicting the harvesting window (yellow) and estimated greater palatine artery trajectory (red) in relation to the guide boundaries

Fig. 4 Three-dimensional printed surgical harvesting guide. (a) Palatal view of the guide seated on the three-dimensional printed study model, demonstrating the harvesting window aperture and passive fit prior to intraoral use. (b) Buccal view of the guide on the study model, confirming full-arch seating and marginal adaptation. (c) Guide seated intraorally on the maxillary arch, confirming passive fit and stability prior to incision

Fig. 5 Palatal graft harvesting sequence. (a) Harvesting incisions performed with the scalpel blade maintained in continuous contact with the guide borders. (b) Harvested connective tissue graft (approximately 15 × 5 × 1.5 mm) following de-epithelialization, with dimensions verified using a periodontal probe. (c) Palatal donor site following graft removal

Fig. 6 Clinical sequence at the recipient site, tooth 23. (a) Baseline presentation showing gingival recession defect. (b) Initial incision for tunnel preparation at the recipient site. (c) Full-thickness tunnel confirmed with periodontal probe, extending mesially and distally to accommodate the graft. (d) Immediate postoperative view following graft introduction and stabilization with non-resorbable polypropylene sutures. (e) 7-day follow-up showing initial soft tissue coverage with no signs of graft exposure or necrosis

Fig. 7 Palatal donor site healing. (a) 7-day follow-up showing progressive tissue repair. (b) 14-day follow-up with uneventful healing and no signs of dehiscence or infection

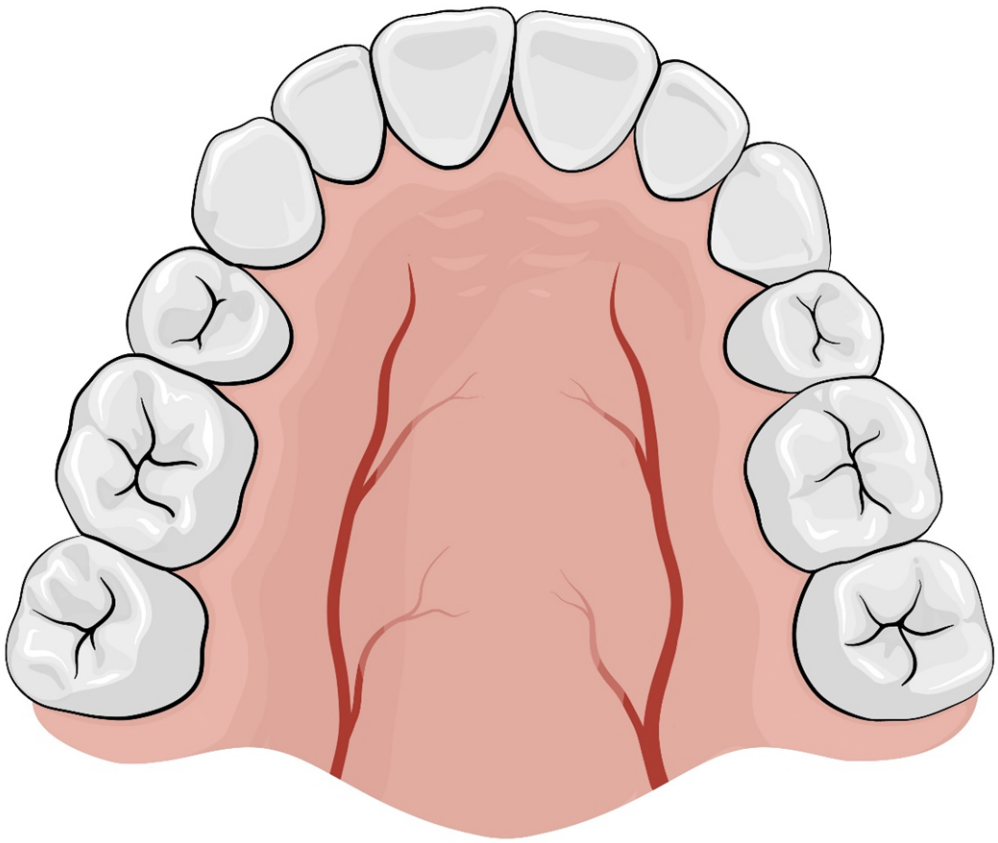


Figure 1

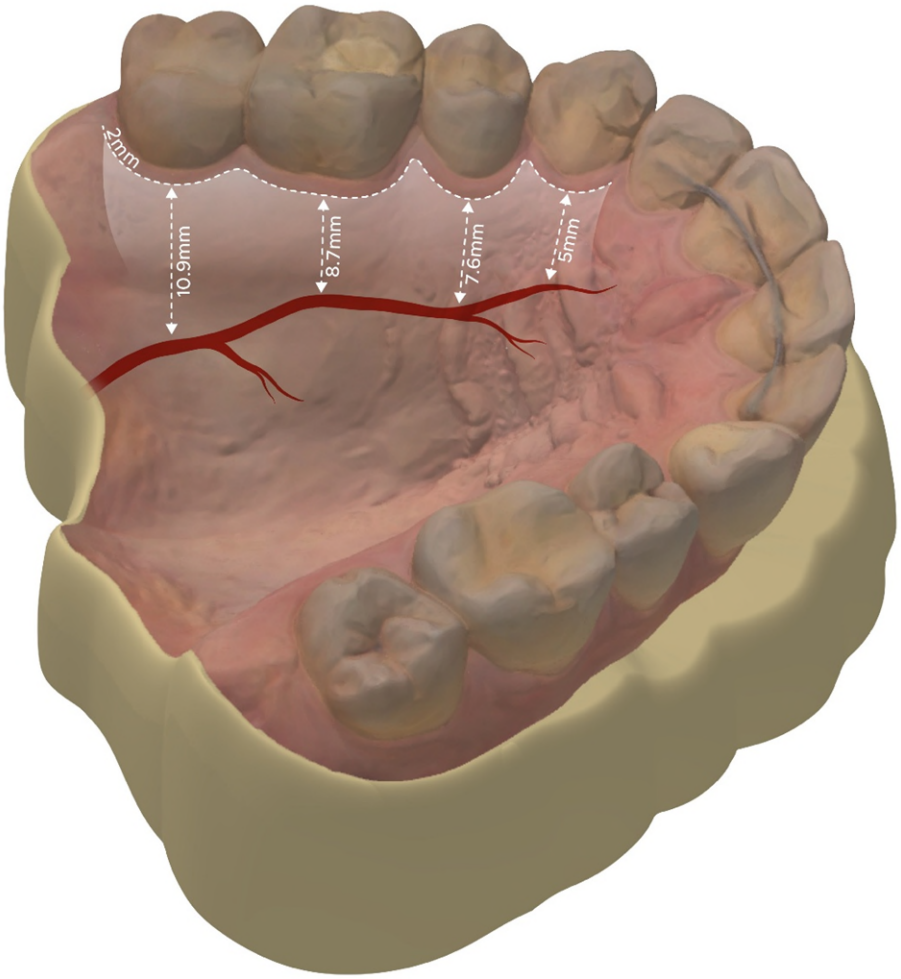


Figure 2

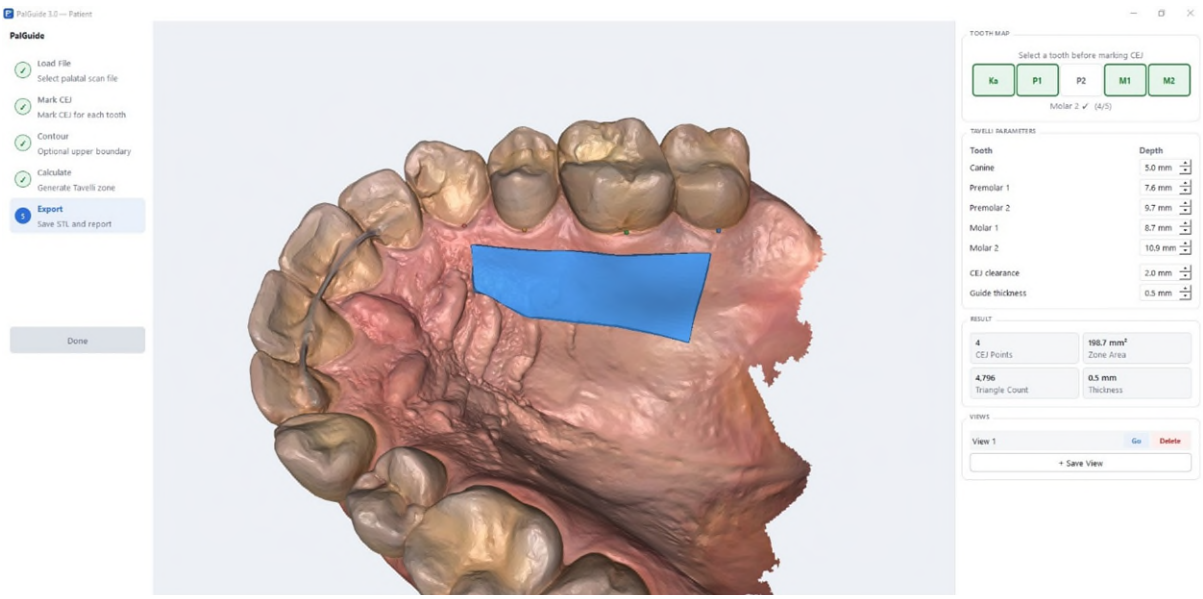

PalGuide 3.0 — Patient
PalGuide
Load File
Select palatal scan file
Mark CEJ
Mark CEJ for each tooth
Contour
Optional upper boundary
Calculate
Generate Tavelli zone
Export
Save STL and report
Done
TOOTH MAP
Select a tooth before marking CEJ
Ka
P1
P2
M1
M2
Molar 2 ✓ (4/5)
TAVELLI PARAMETERS
Tooth
Depth
Canine
5.0 mm
Premolar 1
7.6 mm
Premolar 2
9.7 mm
Molar 1
8.7 mm
Molar 2
10.9 mm
CEJ clearance
2.0 mm
Guide thickness
0.5 mm
RESULT
4
CEJ Points
198.7 mm²
Zone Area
4,796
Triangle Count
0.5 mm
Thickness
VIEWS
View 1
Go
Delete
+ Save View

Figure 3a

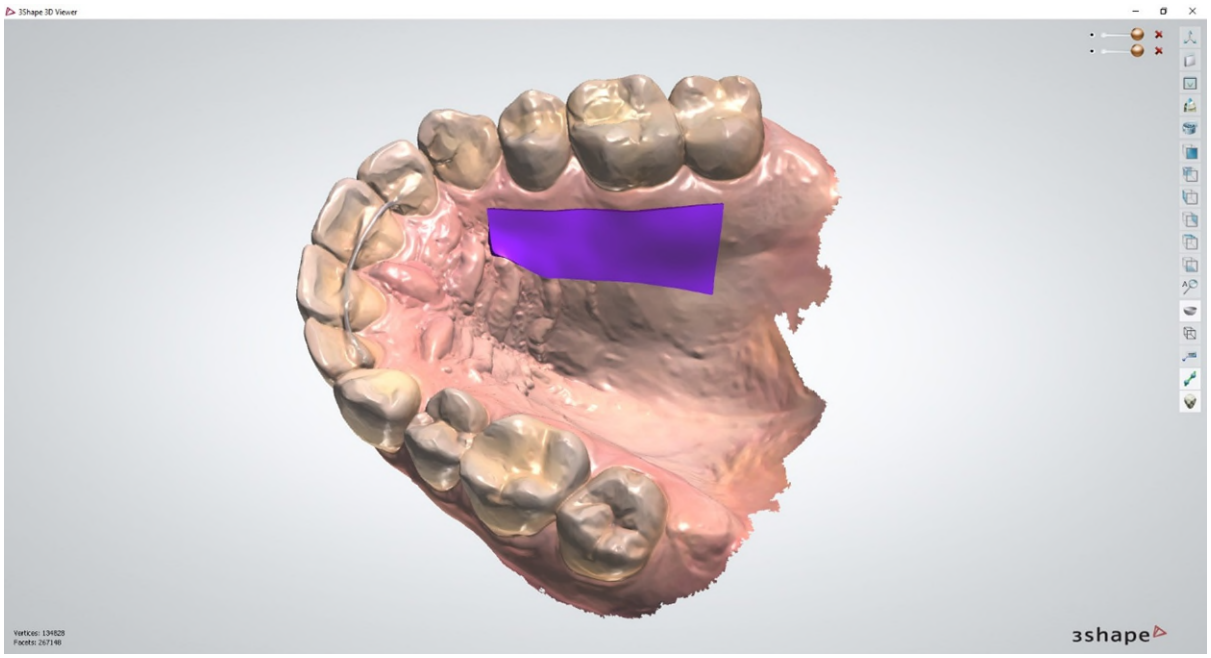


Figure 3b

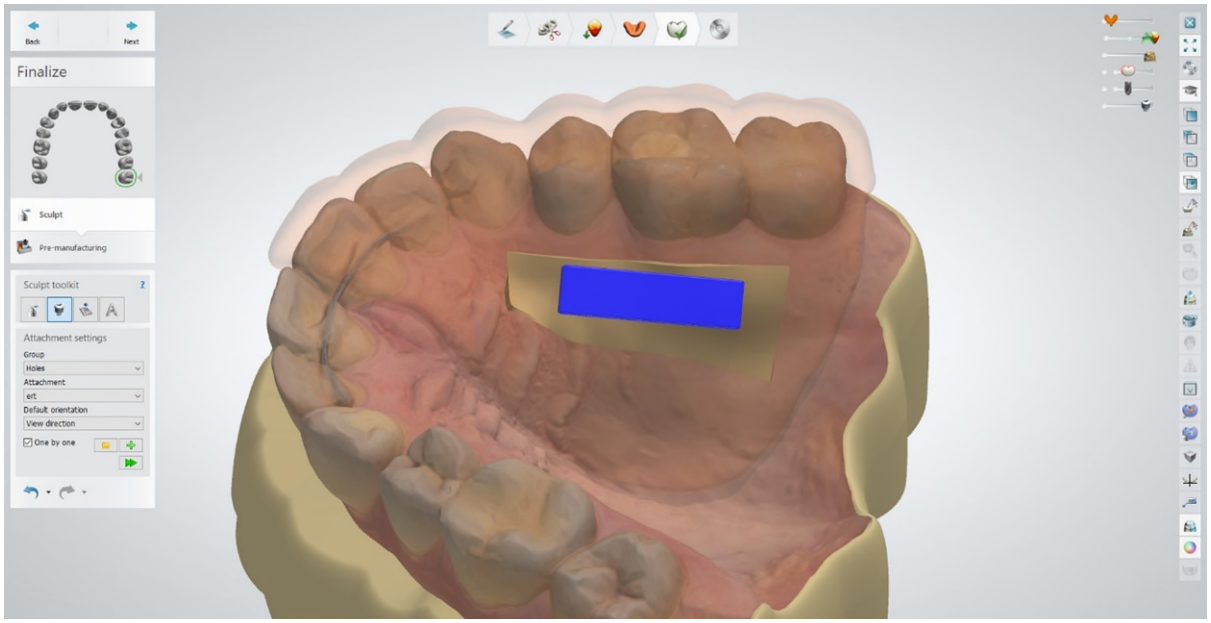

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Figure 3c

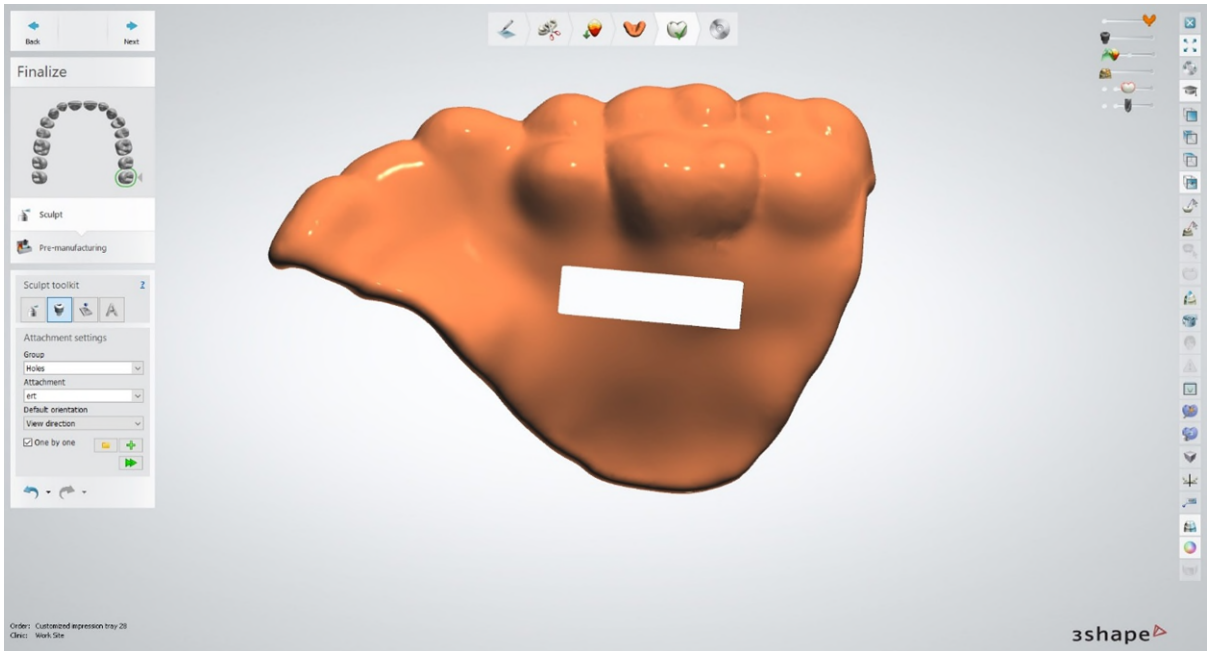

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Figure 3d



Figure 3e

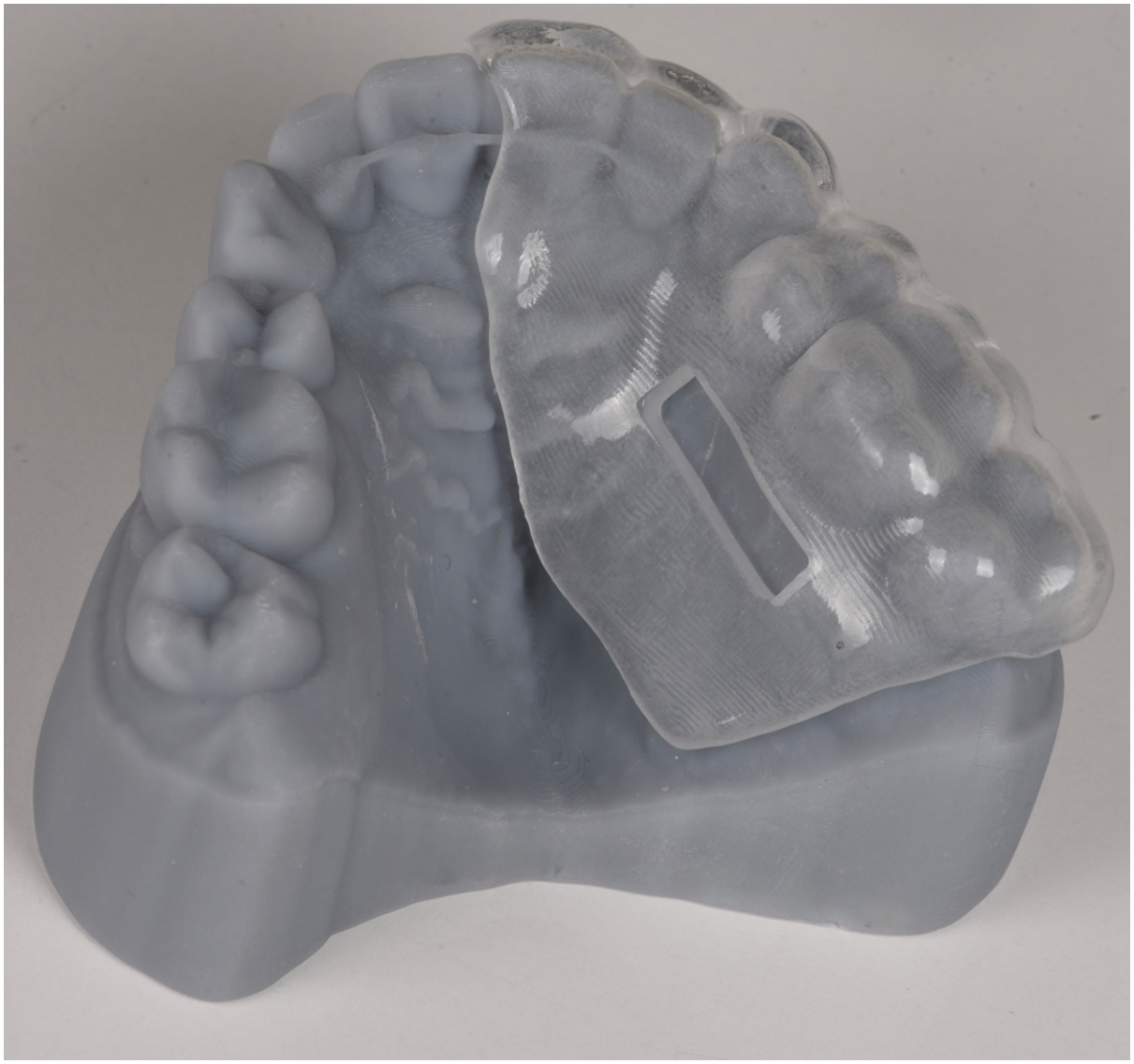


Figure 4a



Figure 4b

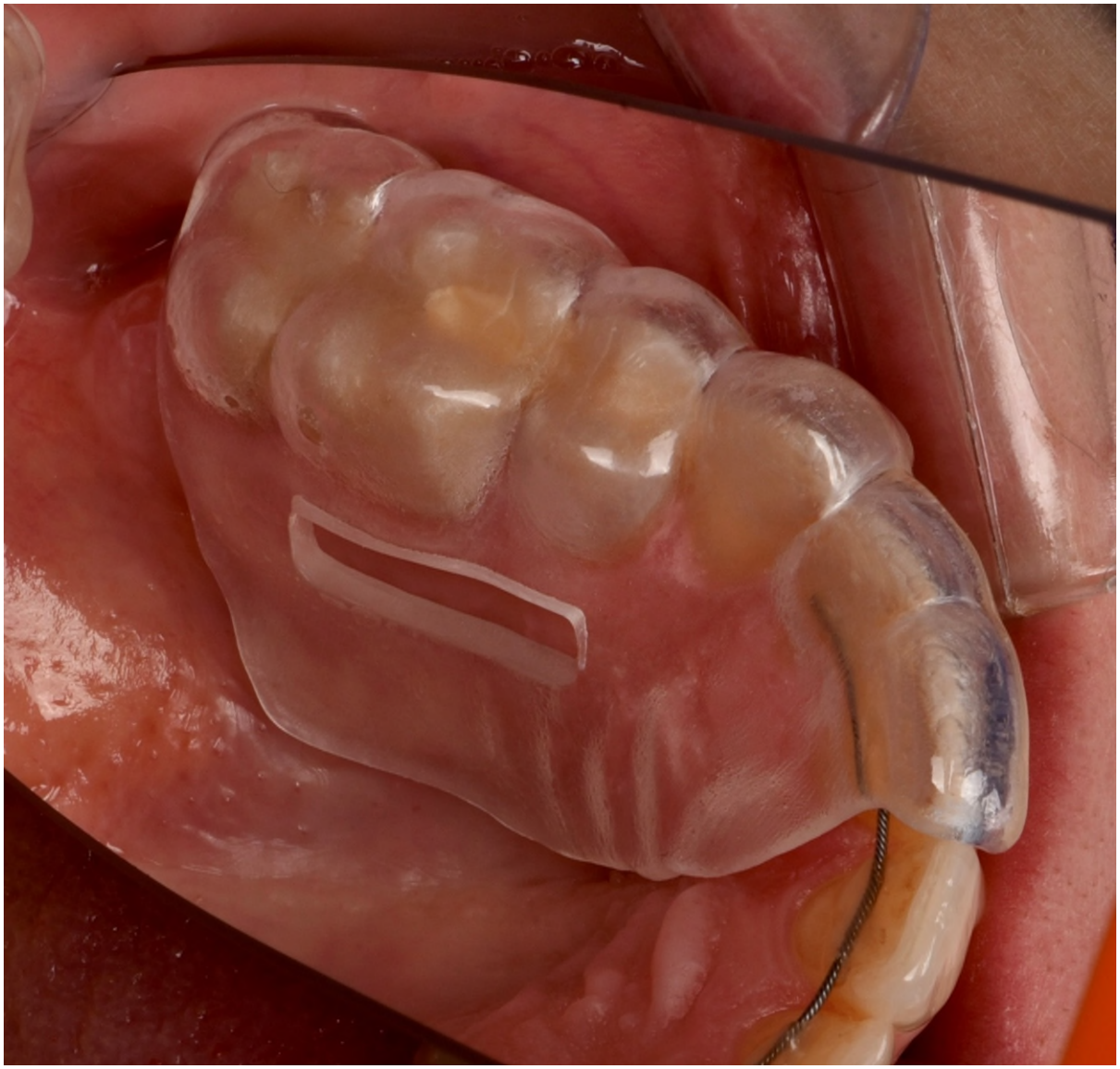


Figure 4c

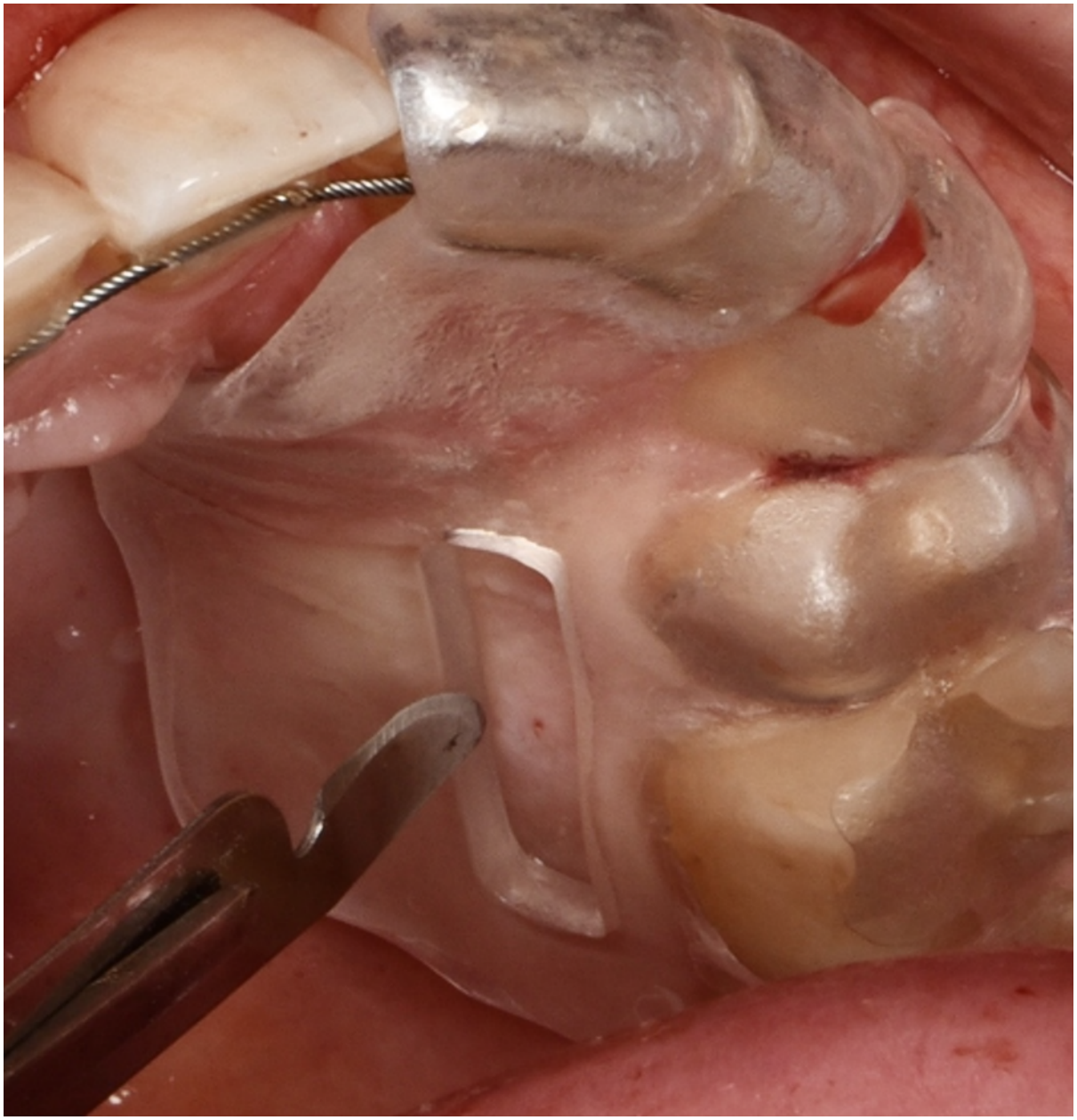


Figure 5a

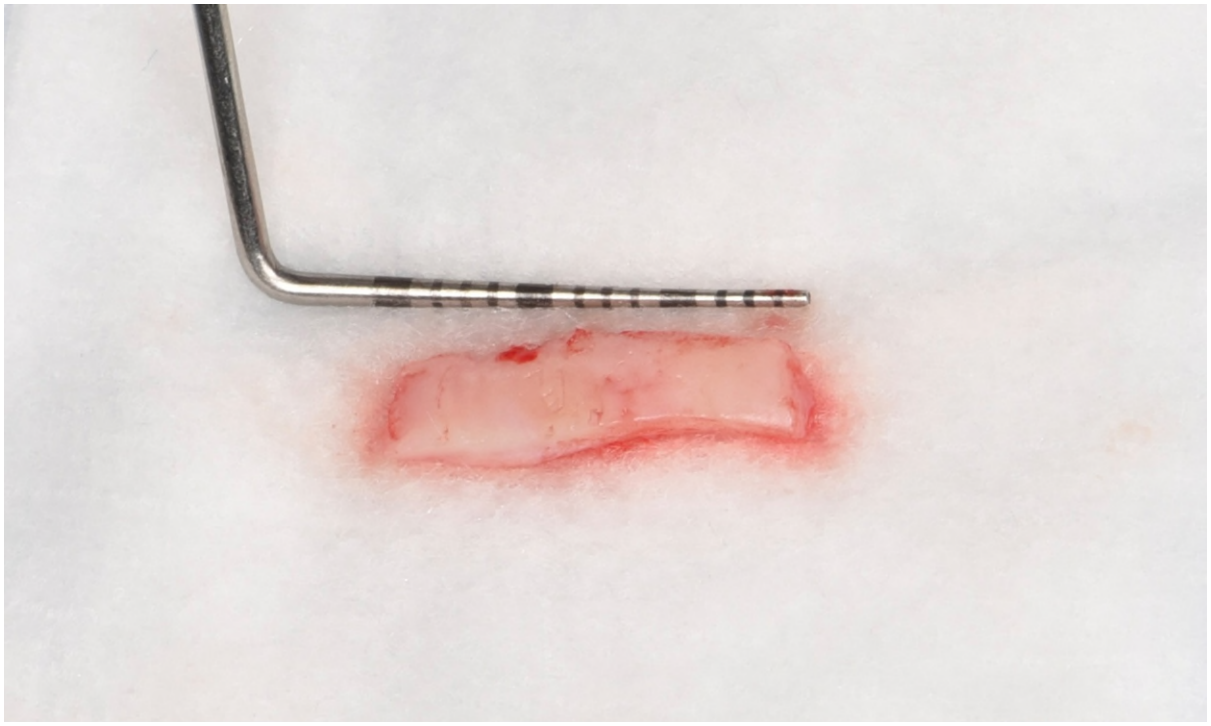


Figure 5b



Figure 5c



Figure 6a



Figure 6b



Figure 6c

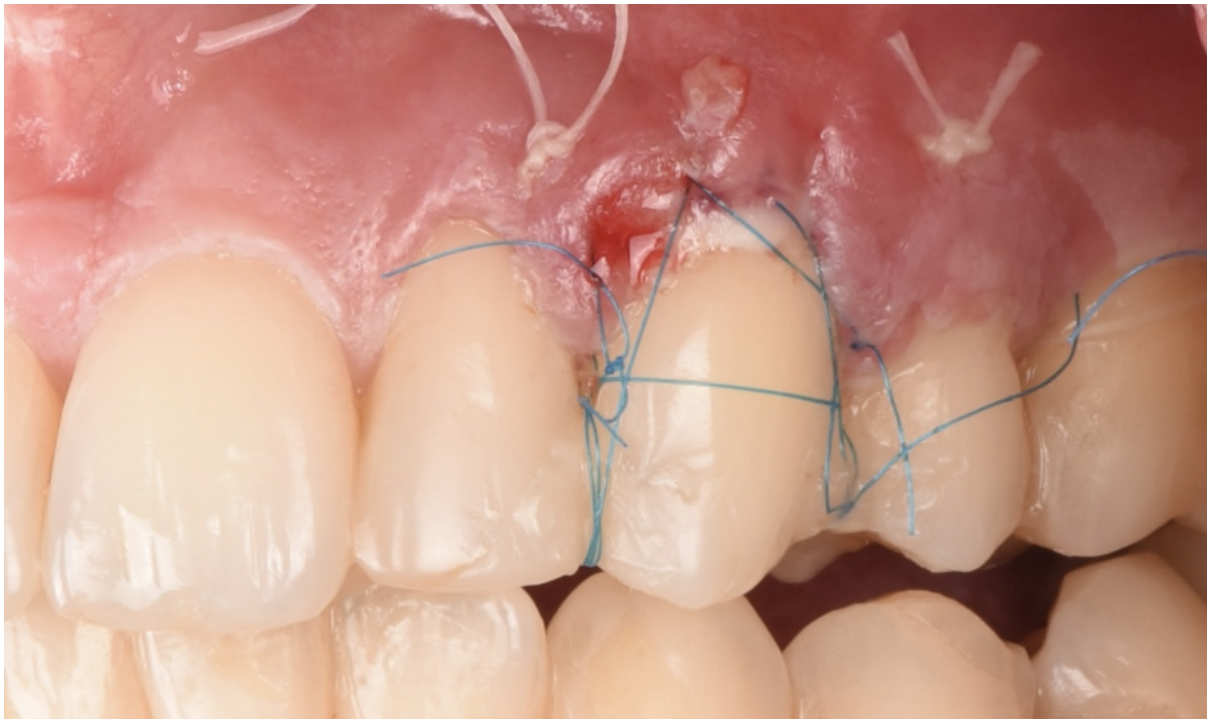


Figure 6d

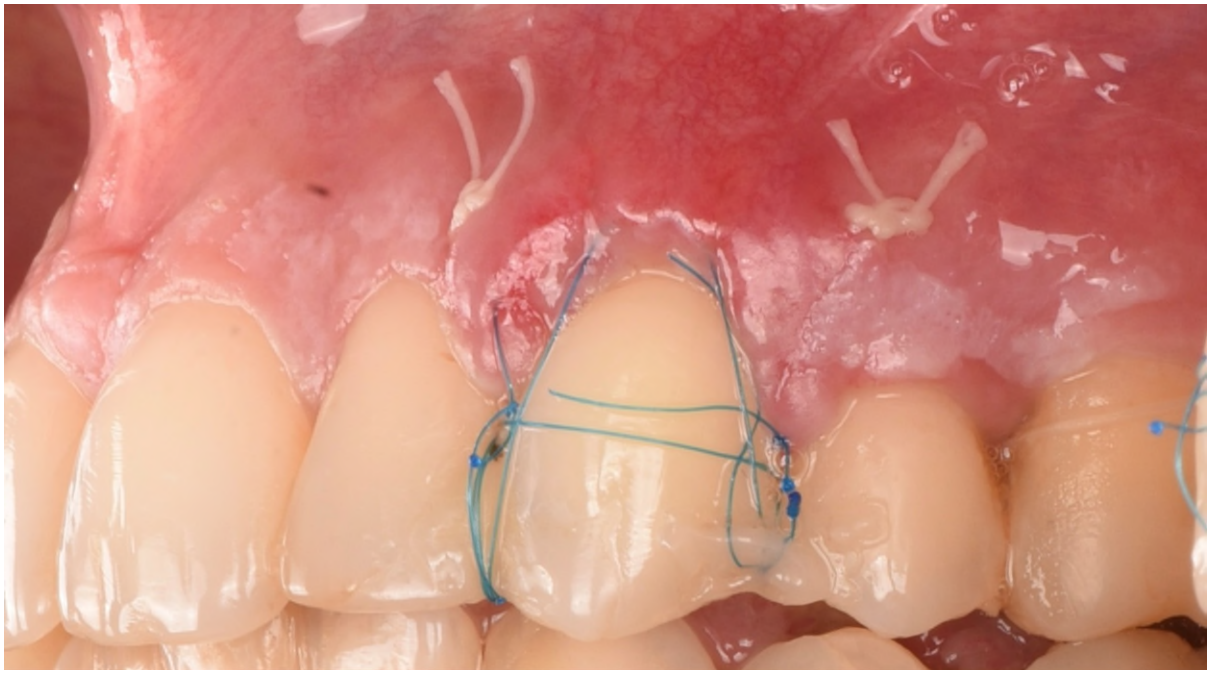


Figure 6e



Figure 7a



Figure 7b