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REVIEW ARTICLE

Anatomy-driven complexity classification for soft-tissue tunneling procedures

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Abstract

Background: The tunnel technique (TUN) preserves the integrity of the papilla by creating envelope flaps that allow for the insertion of a connective tissue graft, and/or biomaterials.

Methods: (1) A comprehensive overview of tunneling flap procedures in the treatment of gingival recessions (GRs) for soft tissue coverage is presented and (2) A classification system for soft and hard tissue anatomy of GR sites which may aid the clinician in determining the surgical complexity is being introduced.

Results: A novel clinical classification system is proposed to illustrate complexity levels determined by soft and hard tissue anatomy of GR sites such as the mucogingival junction proximity to the gingival margin, bone morphotype, and mucosal margin thickness.

Conclusions: TUN is highly effective in treating single/multiple GRs. Its limitations are related to variability in surgical site anatomy and operator expertise. A classification system based on anatomical soft and hard tissue variations has been proposed to help identify complexity levels encountered during tunneling procedures.

KEYWORDS
complexity, mucogingival surgery, soft tissue, tunnel

Key Points

1. Site-related factors directly impact the surgical variables related to tissue trauma, flap tension, soft tissue management, muscle pull, and wound stability during the healing of gingival recessions (GRs).
2. The achievement of expedited and favorable wound healing is crucial to obtaining quantitative and qualitative success in the treatment of GR and the long-term stability of root coverage.
3. A classification system based on anatomical soft and hard tissue variations has been proposed to facilitate tunneling procedures while respecting surgical principles.

INTRODUCTION

Mucogingival deformities are a group of soft tissue conditions affecting millions of patients. Gingival recession (GR) is the apical migration of the gingival margin beyond the cemento-enamel junction (CEJ) and is accompanied by alveolar bone dehiscence.[1] It occurs frequently in adults and tends to increase with age,[2] and affects populations with low and high standards of oral hygiene.[3–5] Other predisposing factors include lack of keratinized tissue (KT),[2] tooth position, bony dehiscence, abnormal frenum attachments, and orthodontic forces, amongst others.[6–8] Exposure of the tooth root and supporting tissue structures increases the probability of developing dental hypersensitivity, root caries, soft tissue discomfort, inflammation, plaque accumulation, and esthetic concerns. Therefore, GR treatment may be indicated with the presence of symptoms and/or esthetic appearance is compromised.[1,8]

Surgical approaches such as mucogingival procedures and guided tissue regeneration have shown positive outcomes in correcting GR.[9] Several systematic reviews and randomized clinical trials have shown the successful use of free gingival grafts, subepithelial connective tissue grafts,[1] and CTG when combined with the coronally advanced flap (CAF).[10] With the advent of minimally invasive techniques and the high esthetic demands of the patients, other surgical techniques such as the tunnel technique (TUN),[6,7,11–14] modified coronally advanced tunnel,[15] vestibular incision subperiosteal tunnel access (VISTA),[13] pinhole surgical technique (PST)[12] and laterally closed tunnel (LCT)[7] have gained popularity.[16,17]

TUN preserves the integrity of the papilla by creating envelope flaps that allow for the insertion of CTG[6,11,15,18] and/or biomaterials.[12,13] While this technique was originally indicated for the treatment of GR, it has been successfully applied to a variety of clinical scenarios.[14,19] These include soft-tissue ridge augmentation, second-stage implant surgery, phenotype modification, and alveolar ridge preservation. The advantages of this technique are the preservation of blood supply from the collateral circulation, minimal surgical trauma at the recipient site, intimate contact with the graft, a decreased tendency for graft shrinkage, wound stability, and maximized healing potential.[7,11,13,14]

Prognostic factors play a crucial role in the overall performance and predictability of reconstructive periodontal plastic surgery. They can be divided into patient-related, site-related, and technique-related factors. In this study, the focus is on tooth-site-related factors as they directly affect the technique and course of the surgical procedure. The aims of this study are (1) to provide a comprehensive overview of tunneling flap procedures in the treatment of GRs for soft tissue coverage, and (2) to introduce a classification system for the soft and hard tissue anatomy of the GR site which may aid the clinician in determining the surgical complexity of the tunneling approach.

MATERIALS AND METHODS

An electronic and manual literature review was performed by two independent reviewers (Amanda B. Rodriguez and Diego Velasquez) using PubMed, EMBASE, and Medline, covering studies published through January 2023. The list of employed terms is as follows: ((((tunnel) AND (tunneling)) AND (technique)) AND (gingival recession)) AND (soft tissue). Articles that met the following criteria were included in this review: 1) surgical treatment of GR(s) with TUN was described, 2) encompassed randomized clinical trials, case-control studies, cohort studies, case series, or case reports, 3) TUN with remote incisions for access. Exclusion criteria were: 1) incision of the papilla. A total of 50 articles were extracted after removing duplicates. Out of these 50 articles, eight articles were found to be relevant. For aim 2, a classification is proposed to assess the surgical complexity of tunneling procedures based on several clinical scenarios.

RESULTS

Successive development of the tunneling approach

Since the introduction of TUN, modifications have been proposed to improve the technique. Raetzke[6] was the first to describe a surgical technique to cover localized GR using an envelope flap. An intrasulcular beveled incision was used to remove the sulcular epithelium followed by scaling and root planing (SRP) and conditioning of the root surface with citric acid. A partial-thickness envelope was created to allow the insertion of a semilunar CTG and to cover the denuded root surface. A cyanoacrylate adhesive was used to secure the graft, and no sutures were required.[6] A modification by Allen[11] introduced a supra-periosteal partial-thickness envelope for the treatment of isolated and multiple GR. Like Raetzke, an intrasulcular beveled incision was made but the root surface was conditioned with SRP and abundant saline irrigation. In this technique, the interdental papilla was undermined for better graft adaption. A CTG graft was later sutured with vertical mattress suture points for close adaptation and stabilization[11] (Table 1).

Later, Zabalegui et al.[18] introduced a modification for the treatment of multiple GR and named this technique a 'tunnel'. In this case, a supraperiosteal tunnel was elevated, the interdental papilla was raised from its alveolar bone, and a CTG graft was positioned in the tunnel and sutured with vertical mattress suture points without coronal advancement. In addition, a modified microsurgical tunnel approach was introduced by Zuhr et al.[20] This technique proposed the use of microblades, newly designed tunneling knives, and 6-0 or 7-0 sutures to reduce surgical trauma. On the other hand, Aroca et al.[21] proposed a full-thickness envelope flap, while elevating the interdental papilla from the bone. Root surface conditioning involved SRP and ethylenediaminetetraacetic acid (EDTA) to create a smooth surface and eliminate the smear layer. Then, modified suspended mattress suture points were used to advance the flap coronally using composite at the teeth contact points to avoid the flap collapsing during healing.

In 2011, Zadeh proposed a modification for the treatment of isolated maxillary anterior GR with a VISTA technique.[13] Initial tooth preparation included SRP and root surface conditioning with odontoplasty and EDTA to eliminate the smear layer. A vertical vestibular access incision was made in the midline frenum as an optimal location to provide access to the anterior maxilla. A full-thickness envelope flap was made to create a subperiosteal tunnel and elevate the interdental papilla with newly designed microsurgical

TABLE 1 Summary of the tunneling techniques.

Author (year)	Raetzke[6]	Allen[11]	Zabalegui et al.[18]	Zuhr et al.[20]	Aroca et al. 2010[21]	Zadeh[13]	Chao[12]	Sculean and Allen[7]
Technique	Envelope	Supraperiosteal envelope	Tunneling flap procedure	Modified microsurgical tunnel technique	Modified tunnel	Vestibular Incision Subperiosteal Tunnel Access (VISTA)	The Pinhole Surgical Technique (PST)	Laterally Closed Tunnel (LCT)
GR indication	–	Miller I, II	Miller I, II	–	Miller III	Miller I-IV	Miller I, II, III	Miller I, II, III
Location	–	–	–	Anterior maxilla	Maxilla or Mandible	Maxillary anterior	Maxillary or Mandibular	Mandibular
Extension	Isolated	Isolated or multiple	Multiple	Isolated	Multiple	Isolated or multiple	Isolated or multiple	Deep isolated
Root surface conditioning	SRP + citric acid	SRP + saline irrigation	–	–	SRP + Ethylenediaminetetraacetic Acid (EDTA)	SRP + odontoplasty + 24% EDTA	SRP + odontoplasty	24% EDTA
Intrasulcular incision	Beveled	Beveled	Yes	Yes	Yes	Yes	Yes	Yes
Vestibular access incision	–	–	–	–	–	Vertical	Horizontal (alveolar mucosa)	–
Partial thickness (PT)/Full-thickness (FT)	PT	PT	PT	PT	FT	FT	FT	FT
Papilla elevation	No	Yes	–	Yes	Yes	Yes	Yes	–
Graft type	CTG	CTG	CTG	SCTG	CTG	–	–	SCTG
Biomaterials	–	–	–	–	Enamel Matrix Derivate (EMD)	Collagen membrane + beta-tricalcium phosphate (β-TCP) hydrated with Platelet Derivate Grow Factor BB (PDGF-BB)	Collagen membrane or Acellular Dermal Matrix (ADM)	
Positioned	–	Coronally	–	Coronally	–	Coronally at the papillary level	Coronally beyond CEJ	–
Sutures	Cyanoacrylate adhesive	Vertical mattress	Vertical mattress	Vertical mattress	Modified horizontal mattress	Modified horizontal mattress bonded to the tooth with composite. Single sutures at the vestibular access incision	None for collagen membrane and sling for ADM	Modified mattress, sling,

periosteal elevators. Later, a collagen membrane and the mucogingival complex were advanced coronally at the papillary level with modified horizontal mattress suture points bonded to the tooth with composites. Another iteration introduced by Chao[12] describes the PST. In this case, a minimal horizontal vestibular access incision is made in the alveolar mucosa to elevate a full-thickness subperiosteal tunnel elevating two adjacent papillae on each side of the GR. This horizontal extension of the flap allowed for free mobilization and coronal positioning beyond the CEJ. A sling suture was used to suture an acellular dermal matrix (ADM) while the collagen membrane was stabilized under the papilla. More recently, Sculean and Allen introduced the LCT. The indication for this technique is deep isolated mandibular GR. A slightly beveled intrasulcular incision is made using microsurgical blades followed by a full-thickness flap. The novelty of this technique was using the mesiodistal approximation of the margins of the GR to cover a greater part of the exposed root surface.

The TUN technique offers positive esthetic outcomes and mean root coverage (mRC) of 87.9% and 82% for multiple and isolated GRs, respectively, and complete RC (CRC) of 57.5% and 47.2%.[8,22] According to a recent systematic review and meta-analysis, the CRC rate shows a statistically significant correlation with recession depth ≤ 2.5 mm, partial-thickness flap reflection, and the smaller suture diameter (≥ 6-0).[8] These positive outcomes may be associated with its conservative flap design, the greater blood supply for graft nutrition, and reduced patient morbidity.[14,18] A list of advantages has been summarized across the studies (Table 1). Additionally, the use of CTG combined with the TUN technique showed the best outcomes for mRC, as well as increasing the KT. The use of biomaterials such as ADM, enamel matrix derivate, resorbable collagen membranes, and beta-tricalcium phosphate hydrated with platelet-derived growth factor-BB showed positive outcomes and may be used as alternatives to autogenous donor tissue.

Site and technique-related factors

Although several systematic reviews have assessed the predictability of different surgical techniques for root coverage,[9,22–24] evidence regarding the TUN remains sparse. Nonetheless, unfavorable outcomes may be associated with impaired or compromised healing due to site anatomical variations which may increase the surgical complexity. Technique-related factors have an immediate impact and predictability of the surgical intervention.[14] Therefore, understanding the differences in soft tissue phenotype and osseous morphotype may give the clinician an opportunity to carefully plan the procedure and ultimately provide a better treatment outcome.

Different challenges associated with tissue handling are encountered when dealing with a thin periodontal phenotype with a narrower band of KT (from 2.75 to 5.44 mm) and a mean gingival thickness (GT) of 0.8 mm or manipulating a thick phenotype with a thicker band of KT (from 5.09 to 6.65 mm) and GT of > 1 mm.[2] Flap preparation for the TUN technique is controversial in the literature and authors have debated whether full or split-thickness should be used (Table 1). While the TUN technique was described as a split-thickness approach[6,11,18,20] and was intended to enhance flap mobility and adequate advancement, a full-thickness approach has been shown to reduce the risk of flap perforation and results in a higher probability of CRC.[8,22] Bone morphotype is another challenging factor to consider during flap elevation. Thicker bone morphotypes, which are rarely associated with GR, show an average buccal bone thickness of 0.75 mm compared to 0.34 mm for thinner bone morphotypes. The presence of a thinner morphotype may influence buccal bone irregularities.[2,25]

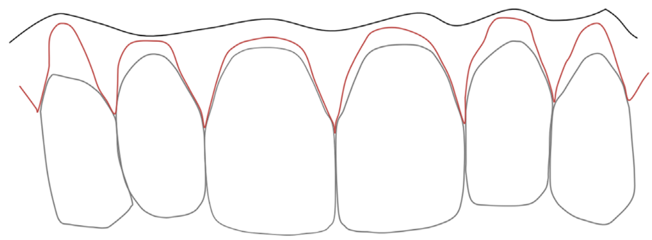

FIGURE 1 Type I. The mucogingival junction (MGJ) is located <2 mm from the gingival margin. There is minimal to no keratinized tissue.

Anatomical complexity classification

This classification aims to describe tissue anatomical variations that once identified will dictate the nature of a customized surgical approach to minimize iatrogenic tissue integrity damage (i.e., perforations), and ultimately focus on achieving predictable and long-term stability outcomes. A novel clinical classification of such scenarios is proposed here.

Based on the mucogingival junction (MGJ) proximity to the gingival margin:

- Type I: The MGJ is located <2 mm from the gingival margin. KT may or may not be present (Figure 1). (See Video S1 in the online *Clinical Advances in Periodontics.*)
- Type II: The MGJ is located within 2–4 mm from the gingival margin. A narrower band of KT can be observed (Figure 2). (See Video S2 in the online *Clinical Advances in Periodontics.*)
- Type III: The MGJ is located >4 mm apically from the gingival margin. A wide band of KT can be observed (Figure 3). (See Video S3 in the online *Clinical Advances in Periodontics.*).

Based on the bone morphotype:

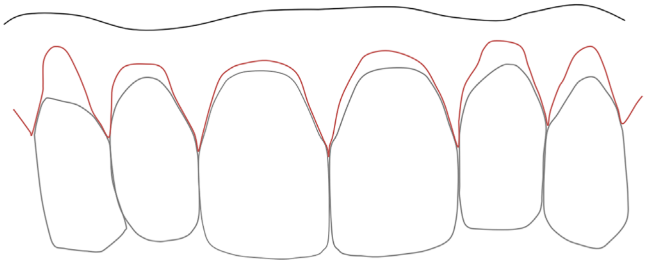

FIGURE 2 Type II. The mucogingival junction (MGJ) is located within 2–4 mm from the gingival margin. A narrower band of keratinized tissue (KT) characterizes this variant.

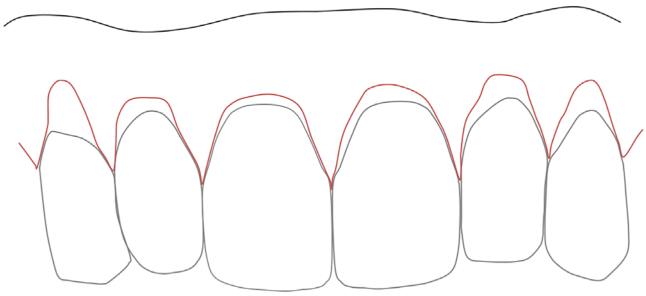

FIGURE 3 Type III. The mucogingival junction (MGJ) is located >4 mm apically from the gingival margin. A wide band of keratinized tissue (KT) is characteristic of this variant.

This is determined by the tactile feedback experienced during instrumentation associated with the tunneling procedure. As the instruments employed are advanced while developing the tunnel, bone irregularities are haptically identified when present.

Class A: The buccal bone shows a smooth profile through the GR site (Figure 4A).
Class B: The buccal bone shows irregularities with the presence of bone concavities and exostosis (Figure 4B).

Based on the thickness of the mucosal margin:

Subtype 1: Thick phenotype of ≥ 1 mm (Figure 5A).
Subtype 2: Thin phenotype of <1 mm (Figure 5B).

DISCUSSION

TUN has been found to be a highly effective technique in treating single and multiple GR lesions. Several authors have described variations in terms of split or full-thickness flap elevation, papilla elevation, coronal advancement, and biomaterial substitutes. Accelerated wound healing, maximizing wound stability, and improved esthetics encouraged some authors to further refine the approach.[20] This undoubtedly resulted in demanding, technique-sensitive procedures. The advent of minimally invasive surgical techniques led by a microsurgical approach that utilizes microblades, microsurgical periosteal elevators, and micro sutures. Therefore, the clinician's skill and expertise are vital to obtaining the desired treatment outcome.

It has been reported that the TUN technique is more effective in terms of mRC and CRC and in treating maxillary and Miller class I and II or RT 1 GR.[26,27] Its limitations include areas with interproximal attachment loss (Miller class III or Cairo's RT2 and RT3), mandibular location in proximity to the mental foramen, and clinician surgical expertise.[8,26–28] However, long-term data is still lacking, and randomized clinical trials are needed to compare the TUN technique in single and multiple GRs. This new classification system could inform the diagnostic and surgical treatment planning phases to achieve positive clinical outcomes. Site-related factors directly impact the surgical variables related to tissue trauma, flap tension, soft tissue management, muscle pull, flap thickness related to blood supply, and wound stability during healing.[23] Similar factors have been recently identified as part of a proposed classification to evaluate the difficulty of the treatment of isolated GR using CAF.[29] Recommendations for the proper surgical approach should be evaluated individually and not only focusing on the recession types and their modifications. Patient-related factors and other anatomical considerations should be analyzed to provide a more predictable outcome and to improve the patient's quality of life.

For Type III MGJ, the presence of a wider band of KT during healing is positive from the biomechanical point of view because this implies less muscle pull and better graft stabilization. From the surgical point of view, elevating a tunnel via intrasulcular access may be more challenging when having a wide band of KT. In this situation, a vertical vestibular access incision in the alveolar mucosa may be considered to allow the clinician to elevate the soft tissue from the alveolar bone beyond the MGJ. Lateral and coronal instrumentation access may help to release the KT to the most apical aspect of the MGJ and facilitate mobility and advancement. On the contrary, intrasulcular-driven tissue displacement in an MGJ Type I is facilitated by the lack or minimal presence of attached gingiva and will not require a vestibular access incision to achieve a release. From a biomechanical point of view, graft stability may be challenged due to high muscle insertion and pull during healing. MGJ Type II may be approached entirely from the gingival margin without a vestibular incision. It is worth noting that it is not unusual that a GR site may be framed by a combination of two or more of these soft tissue anatomical conditions on adjacent teeth which are part of the tunnel preparation. For instance, it is common to find a tooth exhibiting GR showing minimal to no attached gingiva surrounded by teeth with no GR and wide bands of attached gingiva. That is why the diagnosis and treatment approach is dictated not only by the tooth or teeth showing GR but also by those teeth adjacent to the area to be treated since those teeth will be part of the tunneling elevation process (Figure 6).

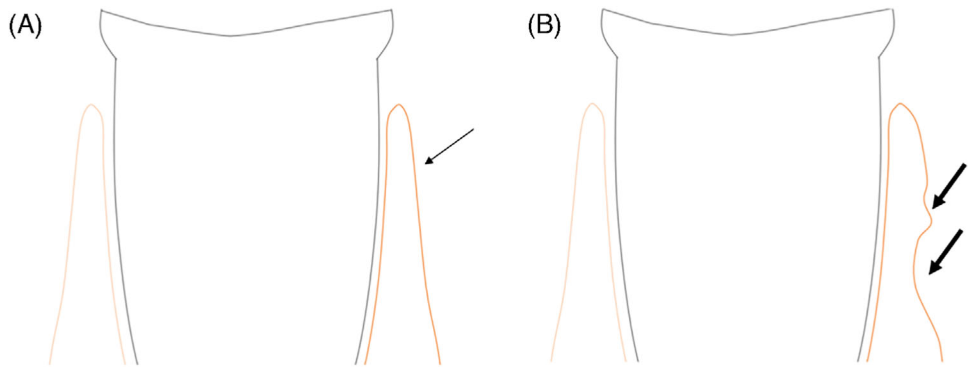

FIGURE 4 (A) Class A: Buccal bone associated with the gingival recession (GR) site is characterized by a smooth and even profile (thin arrow). (B) Class B: Buccal bone associated with the GR site is defined by an irregular profile due to the presence of concavities and exostosis. (Thick arrows).

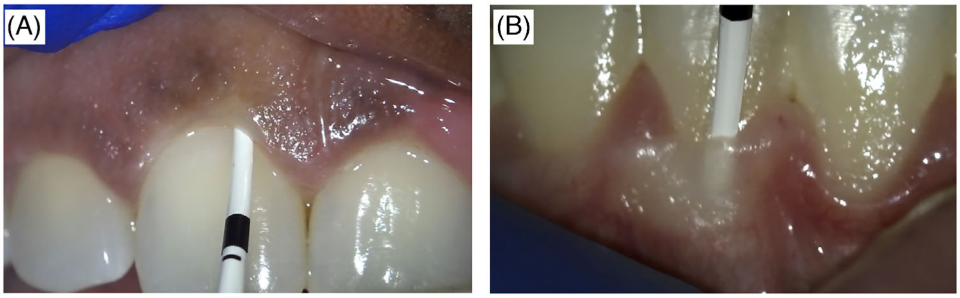

FIGURE 5 (A) Subtype 1: A thick phenotype is observed in this photograph. The periodontal probe cannot be seen through tissues. (B) Subtype 2: Thin phenotype of <1 mm. The periodontal probe can be easily seen through tissues.

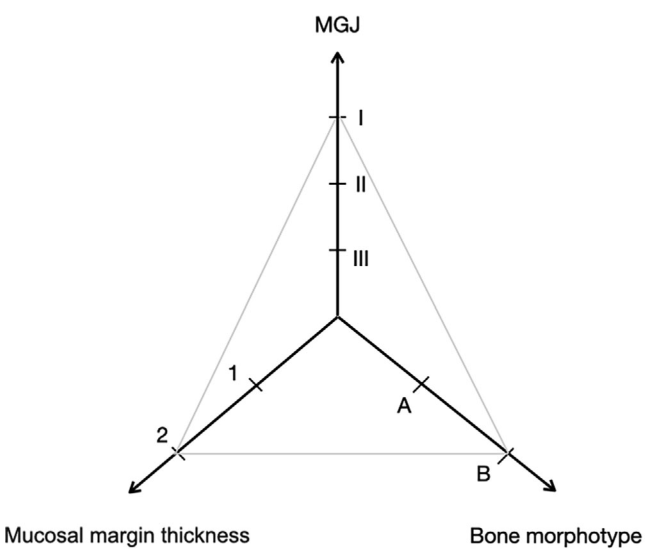

FIGURE 6 Anatomical complexity classification diagram. The larger the area the greater more surgical complexity.

Taking into consideration the bone morphotype classification, Class A will not require additional incisions to facilitate the creation of a tunnel due to a continuous, smooth, and even bone plate. However, when tunneling a type B class morphotype, a vertical vestibular access incision creates a full-thickness tunnel to bypass bone defects and concavities thus reducing the risk of flap perforations or tissue lacerations which may lead to wound dehiscence. Regarding tissue phenotype, Subtype 1 may be handled with a partial-thickness approach and with ease of reflection from coronal to apical, whereas Subtype 2 requires a full-thickness flap and lateral reflection via a vestibular vertical access incision may be considered to prevent perforation.

Clinicians may examine possible surgical approaches to individual cases by considering tissue anatomy during the diagnostic phase. Some cases with a wide band of KT (MGJ Type III), an irregular bone profile (morphotype Class B), and thin tissues (Subtype 2) may not be the preferred choice for TUN. Instead, other approaches ought to be considered to achieve predictable outcomes and long-term tissue maintenance.

CONCLUSION

The present article reviewed the design and applications of the TUN technique and its modifications through the years. It has been shown that TUN is highly effective in treating localized/multiple GRs. Its limitations are related to surgical site variable anatomy and operator expertise.

The achievement of fast and favorable wound healing is crucial to obtaining quantitative and qualitative success in the treatment of GR and the long-term stability of CRC. Negative outcomes may be associated with a lack of planning in the treatment phase and surgical complications leading to wound dehiscence, negative volumetric defects, and fibrotic tissue formation.

Classification systems are valuable communication tools that help expedite the understanding of clinical scenarios and diagnostic conditions. These communication tools establish a common ground that facilitates the execution of tasks and completion of procedures in an orderly and efficient manner. A classification system based on anatomical soft and hard tissue variations has been proposed to facilitate procedures while respecting surgical principles. This communication tool will help guide clinicians with flap design decision-making during root coverage surgical procedures. Validation of classification systems by conducting further studies incorporating reliability tests is recommended for future research.

AUTHOR CONTRIBUTIONS

Amanda Rodriguez: Project administration (lead); resources (lead); visualization (support); writing original draft (lead) and formal analysis (equal). **Hsun-Liang Chan**: Critical review; editing (equal) and formal analysis (equal). **Diego Velasquez**: Conceptualization (lead); visualization (lead); project administration (support); formal analysis (equal) and writing; critical review and editing (equal).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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