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REVIEW ARTICLE

Minimal invasiveness in gingival augmentation and root coverage procedures

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1 | INTRODUCTION

Writing a review article about minimal invasiveness in gingival augmentation and root coverage procedures is a challenging task.

Primarily, for the presentation of scientific findings and a critical discussion of the results, it is to define the key terms used in the present chapter and contextualize them with each other.[1]

According to the National Institute of Health (NIH), minimally-invasive surgery (MIS) is defined as "… surgeries that encompass surgical techniques that limit the size of incisions needed and so lessen wound healing time, associated pain, morbidity and risk of infection". Paired with profound knowledge of anatomy and the implementation of standardized procedures, minimally-invasive surgical procedures have been enabled by the advances of various medical technologies such as microsurgery, laparoscopic surgery, robotic surgery and augmented-reality surgery. Today, MIS techniques are established in a large number of different surgical specialties and their patient benefit is proven by a meticulous scientific approach and suitably designed trials.[2]

In the domain of periodontal plastic surgery (PPS),[3] where gingival augmentations and root coverage procedures belong to, the term MIS is often used synonymously with periodontal microsurgery, which refers to a refinement in surgical technique by which normal vision is enhanced through magnification. Such an attempt of definition emphasizes the importance of the technical equipment (e.g. surgical microscopes, loupes, instruments, suture materials), but at the same time badly neglects the importance of the many other variables such as applied physical forces or duration of the intervention, which are directly related to the invasiveness of the surgical procedure.

Based on the guidelines of the present volume, a technique or procedure for gingival augmentation or root coverage should be regarded as minimally-invasive when its effectiveness is combined with the attempt (1) to minimize the extent of the surgical trauma, (2) to limit the intra- and postoperative morbidity with lower incidence and severity of complications, and (3) to eliminate or minimize the need for reconstructive devices such as membranes or graft materials through maximizing the inherent healing potential of the treated lesion. Moreover, periodontal plastic surgical interventions may be classified as "*minimally-invasive*" when they aim at maintaining or improving pre-existing aesthetics or minimizing the need for additional surgical sessions. In the following, we will use the term *minimal invasiveness* when at least 1 of the above-mentioned criteria is fulfilled and, by mutual agreement, we take it for granted that a microsurgically modified procedure aims at reducing the invasiveness.

It is the goal of the present review article to evaluate the current surgical procedures for gingival augmentation and root coverage, to sum up the corresponding clinical and patient-reported results and to critically discuss the benefits of a minimally-invasive approach in consideration of the above-mentioned criteria. Additionally, the clinical application of a minimally-invasive approach in the aforementioned surgical procedures will be diligently balanced with other factors such as cost–benefit ratio, increased learning curve, and its technical sensitivity.

2 | METHODS

In the past 2 decades, a lot of research has been done in the specialty of PPS to increase patient safety and make the surgical outcomes more predictable and consistent.[4,5] Thereby, clinical practice guidelines based on the principles of evidence-based dentistry built the basement for teaching and implementing new knowledge into clinical workflows.[6]

For the present article, we had to carefully balance the Pros and Cons between a systematic and a narrative review and decide on the suitable format. While the former is based on the findings of comprehensive and systematic literature searches in all available resources, with minimization of selection bias and being judged as the gold standard of evidence-based reporting, after a thorough previous literature search and examination, we decided for the format of the *narrative review*. As the term minimal invasiveness is not consistently defined in the literature and randomized controlled trials with *minimal invasiveness* as key variable are scarce, the informative value of a systematic review would have been compromised and a large number of important questions associated with invasiveness would have been unanswered.

In order to minimize the experts' intuitive, experiential, and explicit perspectives on the focused topic in the present narrative review, critical issues were discussed between the 2 authors with the intention to reduce cognitive biases as a method of debiasing. For the treatise of the title topic, namely the discussion of the impact of a minimally-invasive approach on the outcomes of gingival augmentation and recession coverage procedures, we have divided the topic into the following 5 key questions:

1. Which are the influencing factors that characterize minimal invasiveness in Periodontal Plastic Surgery (PPS)?
2. Which are the current procedures and related outcomes of gingival augmentation procedures?
3. How do the aspects of minimal invasiveness influence the results of gingival augmentation procedures?
4. Which are the current procedures and related outcomes of root coverage procedures?
5. How do the aspects of minimal invasiveness influence the results of root coverage procedures?

2.1 | Which are the influencing factors that characterize minimal invasiveness in PPS?

At a first glance, surgical invasiveness seems to be defined by a daunting spectrum of mechanical and biochemical factors on a cellular and molecular level, which determine how soft tissues react. At a closer examination, it cannot be ignored that behavioural aspects on part of the surgeon, comprising all the cognitive processes that lead to clinical and intraoperative decisions, are at least as important as the mechanically applied forces as they—consciously or unconsciously—build the underlying causes of the trauma.

Despite the intricate interconnectedness of the above-mentioned variables characterizing *minimal invasiveness*, for a better understanding, we will subdivide the section of the influencing factors into 3 different levels which will be discussed separately, namely the influence of the (i) the provider, (ii) the surgical procedure, and (iii) the biological processes underlying mucosal healing.

2.1.1 | Provider

In the search of the causative factors for the invasiveness of a periodontal surgical procedure, it seems to be too naïve to believe that just describing the flap design with its technical characteristics is enough to provide us with the desired information. It is estimated that surgical proficiency is based on just 25% technical skills while 75% is nontechnical nature such as decision-making, communication, and teamwork.

Nontechnical skills

Clinical decision-making is influenced by *cognitive biases*, which are specific systematic patterns of judgment that result in thoughts and behaviors deviating from what might be generally concerned as rational or optimal.[7-11] Cognitive biases are inherent to all humans; they are hazardous because they are hardwired in our thinking, and they are strongly influenced by emotions and are processed unconsciously.[12] Hence, cognitive biases can compromise rational decision-making and lead to adverse consequences as they are usually not noticed by the individual clinician. The risks of cognitive biases associated with medical decisions have been described in systematic reviews,[13,14] which also confirmed the extremely high prevalence of cognitive errors across the many different medical specialties.[12]

In the field of PPS, the overconfidence error has been confirmed in a study evaluating the influence of technical and nontechnical skills on surgical performance.[15] Prior to the surgical intervention, the subjects had to value their self-perceived proficiency in periodontal surgery and classify themselves as *novice*, *advanced*, or *expert performers*. Interestingly, the performance values related to self-perceived proficiency were lowest for the group of the self-declared experienced surgeons, followed by the group of the advanced and novice performers. As self-assessed proficiency seems to be a poor predictor for surgical performance, it may seduce clinicians into selecting technically-sensitive interventions that exceed their manual skills and, thus, increase the risks to unnecessarily traumatize the mucosal tissues.

Even if evidence confirms that medical personnel is generally prone to show cognitive biases,[16] and although the importance of nontechnical skills is being increasingly recognized,[17] there is currently little integration of its teaching and assessment with technical skills training.[18] Early recognition of surgeons' cognitive biases (e.g., overconfidence, illusion of control) and personality traits (e.g., stress tolerance, communication skills) are crucial to optimize pre- and intraoperative decisions and to prevent surgical errors including traumatic tissue manipulation.[19]

Technical skills

Traditionally, the focus in medical education is nearly always on knowledge, means on providing information about the right way to proceed, and then mostly rely on the trainees to apply that knowledge.[20] In contrast to current situation, the bottom line in periodontal surgery is what you are able to do, not what you know, although it is understood that you need to know certain things in order to be able to successfully perform a surgical intervention. A purposeful technical skills training in periodontal surgery, which aims for reducing the operative tissue trauma, must focus on doing rather than on knowing and requires supervision, feedback, and consistent dedication to training over long stretches of time (Figure 1).

Contrary to popular assumptions, evidence from the science of expertise and expert performance suggests that the technical performance of a surgeon does not improve much by clinical experience and increasing knowledge,[21] a finding that has also been confirmed for periodontal surgeons.[15] Practicing the same procedure over and over again in exactly the same way, soon leads to a satisfactory skills level with automated performance, concomitant with flattening of the skills-performance curve. Some studies on the relationship between clinical experience and quality of health care even demonstrate that there is an inverse relationship between the number of years that a clinician has been in practice and the quality of care that the physician provides.[20,22]

In a recent second update of a Cochrane systematic review,[23] the authors examined the effectiveness of continuing professional education for practicing physicians and surgeons. The consensus was that, while it is not exactly worthless, it is not doing much good either. The most effective interventions were those that had some interactive component such as hand's-on training, role-play, or discussion groups. Studies confirm that the overall benefits of continuing education, especially those of didactic interventions (e.g. listening to a lecture), are very small and do not contribute to improvement of technical skills.[24]

Human factors as the field dealing with the interface between the surgeons' hand and the instrument handle is closely related to technical skills and examines the tactile feedback needed to control the application of physical forces to wound margins or to prevent the unwanted crushing effect of an occluding forceps on the delicate mucosal tissues.[25]

A controlled clinical study, designed to evaluate the impact of residual flap tension on the amount of coverage of shallow gingival recessions, nicely showed that applied flap tensions in a very low range (<1 g) are compatible with complete coverages while a residual mean tension of just 6.5 g substantially lowered the probability for a complete root coverage.[26] Even if evidence from studies in periodontal surgery confirms that minimal residual flap tensions are fully compatible with uneventful wound healing,[27,28] such findings support the tenet of *passive wound closure*, which has a clinical implication and raises the question if clinicians are generally able to tactually differentiate such small differences of applied forces.

FIGURE 1 (A) Baseline conditions at lower premolar requiring crown lengthening and increase in KT. (B) An apico-distal shift of buccal papilla was planned. (C) The flap was sutured and surgical papilla were secured in the center of alveolar bone. (D) Soft tissue healing 3 months after surgery.

In a recent study, the 42 included experienced periodontal surgeons had the task to suture a total of 18 flaps with a given target tension, half of them with 0.5 g and the other half with 10 g. The preliminary results clearly demonstrated that clinicians are unable to discriminate between small differences of applied forces on wound margins, showing mean tension values of 105.3 ± 11.8 g in the first task (target tension 0.5 g) and 142.2 ± 4.8 g in the second one. Both, the intra- and inter-individual variabilities exceeded 300% and were more pronounced when very low tensions had to be applied.[29]

A large dataset from different fields such as Braille reading[30] or music performance[31] supports the hypothesis that tactile acuity, which seems to be paramount in PPS in order to control applied forces, can be trained similar as the sense of hearing, the sense of smell, and others do.[32] Therefore, a technical skills training in PPS should not exclusively focus on the execution of the surgical procedure but include elements of the discipline of human factors.[33-35]

2.1.2 | Surgical procedures

In many different surgical specialties, the term *minimally-invasive surgery* has gained widespread acceptance and practically, most of today's surgical subspecialties are using some form of minimal invasiveness. In periodontal surgery of the past 2 decades, a substantial amount of new knowledge has been accumulated that sheds light on the importance of minimal invasiveness in gingival augmentation and root coverage procedures. Hereafter, we will discuss the most predominant factors influencing invasiveness in periodontal plastic surgery.

Flap design & releasing incisions

Clinical reports from the 1990s emphasized the importance of flap and incision designs in order to maintain primary soft tissue closure after regenerative periodontal surgeries in the course of time.[36,37] Thereby, the abstention from releasing incisions seemed to be one of the most important influencing factors in order to achieve a stable wound and to maintain its integrity over the entire period of healing.[38-42] Along with this paradigm shift in regenerative surgeries, similar trends could be observed in root coverage procedures in which the different types of coronally advanced (CAF) or laterally positioned (LPF) flaps with buccal releasing incisions have been replaced by CAF without releasing incisions or envelope, pouch, and tunnel techniques.[43]

Even if the main indication for a root coverage procedure still is the subjective patient's perception of impaired aesthetics, in the majority of studies, the outcome usually measured is not the patient related happiness with the aesthetic appearance but the percentage of mean and the number of complete root coverages.[4] Only few studies addressed the important aspect of the aesthetic outcome based on a reproducible aesthetic score.[44] There is no need to say that an abstention from releasing incisions in the zone of aesthetic priority may reduce the risks for scar formations and adverse aesthetic outcomes and as such the modern tunnel techniques may be considered as a valuable contribution to minimize the invasiveness in periodontal plastic surgery.

Blood supply

Results from angiographic studies on humans documented the negative impact of buccal releasing incisions on the blood perfusion of the injured area. Even without raising a flap, the only releasing incision substantially reduced the blood supply of the surgical site for a duration of up to 96 h after the injury.[45] Thereby, the blood reperfusion of the surgical site seemed to be positively influenced by the mechanical stability of the wound and being delayed when sutures were accidentally lost.[46,47] Not only the fact of releasing incisions decreased the vascularity of the surgically injured site but as well their vertical extension correlated with an increased disturbance of the blood perfusion.[45] An even more negative impact on the vascularity of the mucosal tissues than incision and flap design could be registered for advanced flaps, stabilized and sutured under residual tension.

Obviously, blood supply does not only play a crucial role in flap healing but is at least as important after mucosal grafting. In a series of historical studies on monkeys, the researches shed light on the critical role of the revascularization of free gingival grafts in the wound healing process,[48-50] classifying the healing sequences into 3 phases, the first one named *initial phase* (from 0 to 3 days) in which an avascular plasmatic diffusion from the wound bed is the only source of nutrients for the free gingival graft. That is why placing a free gingival graft over a denuded, avascular root surface in order to cover a gingival recession involves a great risk of failure. The second, the *revascularization phase* (from 2 to 11 days) is characterized by the proliferation of capillaries and establishment of anastomoses between the wound bed and the gingival graft, resulting in a dense network of blood vessels in the graft. In the *tissue maturation phase* (from 11 to 42 days) as the last one, the number of blood vessels gradually decreases to a normal level and the epithelium matures with formation of a keratin layer.

For an uneventful healing of a free graft after gingival augmentation procedures, the initial phase seems to be most critical in this kind of therapy. The invasiveness increases if there is no close contact between the graft and the recipient wound bed as a blood clot or thick layer of exudate may impair the plasmatic circulation resulting in graft necrosis, which, in turn, has an impact on patient morbidity. A gentle wound compression and inverting mattress sutures, firmly adapting the graft to the wound bed, help to achieve the aforementioned goals and belong to the catalogue of minimal invasiveness in gingival augmentation procedure (please see Figure 2).

Flap tension

There is no doubt that applied mechanical flap tension is one of the most critical issues in the discussion of minimal invasiveness in root coverage procedures (see above). Surprisingly, a digital search in Medline database, entering key terms related to passive wound closure in periodontal and implant surgery only provided very few studies including measurements of flap tension after periodontal

FIGURE 2 (A) A 5 mm gingival recession with no residual KT at lower left central incisor in a 11-years girl. Soft tissue was very thin also at adjacent central incisor. (B) A free gingival graft was placed. (C) Soft tissue healing 10 days after surgery. (D) Soft tissue healing 6 months after surgery with full root coverage and excellent amount of KT.

and implant surgeries,[26-28] while most of them did not report on critical threshold values of applied flap tensions.[51-53] From a basic research[54,55] but also clinical perspective, one can conclude that the application of low residual flap tensions (<5 g) seems to be fully compatible with primary wound closures or complete root coverages. Nevertheless, it has to be mentioned that the tactile discrimination of very small differences of applied forces within a range of few grams is almost impossible without a corresponding training.[29]

The impact of enhanced vision (surgical microscopes)

In the field of gingival recession coverage, scientific evidence seems to confirm that a modification of current procedures by using high-power magnification (surgical microscope), microsurgical instruments, and fine suture materials, yields better results compared to those of traditional approaches.[56-59] These studies highlight the surgical microscope as the core component of the microsurgical technique and suggest that its use allows a much more accurate and less traumatic manipulation of the treated mucosal tissues. When similar surgical approaches for the coverage of gingival recessions were directly compared from which one was microsurgically modified, such immediate postsurgical trauma reduction could not be confirmed, at least for the vascular blood supply in the treated areas.[58] Although, the microsurgically treated sites were characterized by a faster recovery of the blood perfusion which surpassed the one of the macrosurgically treated areas, with statistical significance, after only 3 days of healing, assuming that there might be other factors than solely visual acuity that trigger wound healing.[33] As there is no direct interface between visual perception and tissue trauma, the mechanisms that explain the beneficial effects of a microsurgical approach in periodontal surgery are still unclear and require further elucidation. Ergonomics research documents that continuous surgical training with high power magnification helps to enhance fine motor skills,[60,61] which, in turn, may allow to manipulate the delicate mucosal tissues more accurately.

In periodontal microsurgery, fine suture materials belong to the surgical concept and might play a key role in the explanation of the observed tissue reperfusion and improved healing capacity of the mucosa after root coverage procedures. The breaking strength of fine suture threads is much lower compared to conventional ones used in periodontal surgery[62,63] and as such representing the weakest link between the surgeon's hand and the mucosal tissues.

A considerable number of wound healing studies document the importance of the micromechanical environment of the wound area and emphasize the regulatory mechanisms that macroscopically applied forces may have on cell behavior in the wound healing process.[55,64,65]

The use of connective tissue grafts

The use of connective tissue grafts (CTG) in the context of recession coverage procedures will be discussed in detail further down. Clinical research data clearly confirm the beneficial impact of the use of CTG on the amount of coverage of buccal root recessions.[4,66] At a closer look, scientific findings also confirm that the positive effect of a CTG is most pronounced in the treatment of recession defects with an unfavorable soft tissue morphology, corresponding to recession type 2 or 3 (Miller class III and IV), while it has less or no influence on the amount of coverage of type 1 recessions.[67] Such clinical results support the findings from an animal study showing that flaps sutured on denuded dentin surfaces with an interpositioned CTG require much higher forces in the postoperative healing phase to becoming detached from the wound bed compared to postsurgical situations characterized by a direct flap-root surface interface.[68] Thus, the above-mentioned studies investigating the application of CTG in periodontal plastic surgeries, executed on denuded root surfaces, support the hypothesis that CTG may have the potential to mechanically stabilize the wounds and contribute to its' integrity in the course of healing.

To date, the clinical use of CTG still lacks many of the biological explanations about the functional mechanisms of the graft, a fact which complicates its discussion in the context of minimal invasiveness of root coverage procedures. It still is unclear how the vascularity of the wound bed or graft thickness relate to the reperfusion of the graft,[69,70] whether its function is mainly based on mechanical characteristics or if the biological composition has an impact on the healing potential of the recipient surgical site.

2.1.3 | Biological conditions and their impact on wound healing

It has to be noticed that wounds caused by a recession coverage are characterized by a high biocomplexity as hard, acellular, non-vascularized, and non-shedding surfaces of the root are included in the wound area and constitute parts of the wound boundaries.

In order to find the answers how surgical invasiveness may relate to the course of mucosal healing, we have to focus on the early wound healing stages. Although a simplification, the classic division of wound healing into (1) inflammatory, (2) proliferative, and (3) remodeling phases is still useful in understanding both routine and pathologic wound healing.[71] Most basic research studies focus on the interplay of biochemical factors influencing wound healing,[72] but badly neglect the importance of the mechanical cues.

Mechanotransduction in periodontal wound healing

Mechanotransduction, defined as a process that enables cells to convert mechanical stimuli into biochemical or transcriptional changes, is based on experimental findings which document that cells are hard-wired to respond immediately to mechanical stresses transmitted over cell surface receptors that physically couple the cytoskeleton to the extracellular matrix or to other cells.[73,74] The molecular signaling pathways of applied mechanical forces are described for the biological processes in the extracellular matrix,[75] the cell membrane[76] as the interface between the ECM and the cell, for the intracellular mechanical force transmission via the cytoskeleton and even the interface between the cytoplasm and the nucleus of the cell.[65,77] The cells of the oral mucosa and the periodontal ligament, such as fibroblasts and keratinocytes, have been shown to be highly mechanosensitive,[55,78,79] which underlines the potential role of applied mechanical forces in the wound healing process when flaps are manipulated and sutured under tension of different magnitudes.

Micromechanical aspects of the blood clot during healing

Blood clot formation to prevent local hemorrhage and to build a provisional matrix for wound healing is one of the first processes to take place after wounding.[80] The heterogeneity of fibrin as a main component of the fibrin fiber results in blood clots that are characterized by different viscoelastic properites such as rigidity and elasticity. Immediately after clot formation, stability means the resistance of the clot to mechanical stress which is essential to withstand arterial pressure and to stabilize the early wound.[81] After surgical wound closure, the viscoelastic properties of the blood clot might determine how it responds to treatment. A stiff or brittle clot might have a greater tendency to disrupt from a root surface or other wound beds, while those that are more viscous or plastic might deform and maintain their mechanical function.[82] Although not much is known about the relationship between mechanical properties of fibrin and its impact on clinical wound stability, it has been documented on periodontal wounds in a previously mentioned animal experiment[68] that the tissue characteristics of the wound bed have a substantial effect on blood clot stability and adherence—possibly, a plausible explanation for the observed clinical benefit of the use of interconnected CTGs.

In the subsequent wound healing phases, in order to reinforce the wound and initiate wound contraction, fibroblasts have to migrate into the provisional matrix and deposit collagen which requires a local dissolution of the blood clot. Research findings from a study on human blood clots revealed that mechanically stretched fibrin fibers in the blood clot (e.g., by increased wound tensions) are more resistant to proteolytic dissolution, which again, documents the biological mechanisms of mechantransduction and the interconnectedness of applied mechanical forces with undisturbed wound healing.[83] In this regard, it has to be noted that the above-mentioned findings must be viewed from a qualitative perspective than being judged on the basis of absolute numbers and the magnitude of the actually exerted mechanical forces.

The biocomplexity of mucosal wound healing is mirrored in the fact that uneventful healing depends on finely balanced mechanical forces in the microenvironment of the wound. While excessive mechanical stress in the granulation tissue and early connective tissue matrix leads to a delay in healing and increases the risks for adverse outcome, an insufficient amount of mechanical force can have a similar effect, well documented by the ceased phenotypic changes of fibroblasts into myofibroblast[84] or the delay in the morphogenesis and lumen formation of the new capillaries.[74,85]

The above-mentioned scientific findings paired with the clinical observations of improved healing patterns after surgical interventions with best possible control of applied mechanical forces suggest that a mechanomodulatory approach might be a promising way to address the multiple pathways involved in the healing response and, thus, to reduce the invasiveness of the surgical procedure.

2.2 | Which are the current procedures and related outcomes of gingival augmentation procedures?

For decades, the presence of "adequate" amount of attached gingival tissue was considered a key factor for maintenance of gingival health. This issue still represents a very controversial topic. A classical prospective study on dental students suggested that a minimal keratinized tissue (KT) threshold of 2 mm is necessary to prevent further periodontal breakdown.[86]

On the contrary, a prospective 5-year follow-up from the Wennstrom group showed that it is possible to prevent gingival recession progression if careful plaque control is performed although gingivectomy was performed at baseline. Thus, Wennstrom's study confuted the paradigm that a "minimal" amount of gingiva by itself is necessary to prevent the progression of gingival recession.[87] In a historical perspective and as a consequence of these study findings, the excessive amount of clinically executed gingival augmentation procedures in the clinical practice was lowered substantially.

In the modern era, an evidence-based and a taxonomic approach help clinicians to identify specific conditions and estimate predictable benefits of treatment. In the clinical scenario, the thickness of buccal KT, along with its apico-coronal width, has become popular to identify the gingival phenotype. Various methods to assess gingival thickness have been described in the literature including ultrasonic devices[88] and the use of endodontic reamers sticked in the gingival tissue.[89] An explorative study described the use of a periodontal probe and its related visibility in the facial junctional epithelium.[90] Gingiva was defined as thin (≤1.0 mm) or thick (>1 mm) according to the probe detection through the gingiva.[90] This method was found to show a high reproducibility with 85% of inter-examiner repeatability.[90]

A systematic review[91] assessing the periodontal soft tissue morphology suggested 3 possible categories of periodontal phenotype, distinguishing a thin-scalloped, a thick-flat or a thick-scalloped gingival type.

Lately, an extensive review[92] focusing on mucogingival deformities suggested that

1. Thin periodontal biotypes are at greater risk for developing gingival recessions than thicker biotypes
2. Inadequate oral hygiene measures, orthodontic treatments, and cervical restorations increase the risks for gingival recessions especially in the presence of thin periodontal phenotype

Additionally, in the above-mentioned review, a comprehensive checklist has been proposed to evaluate soft and hard tissue characteristics at periodontal sites, including gingival recession classification,[93] presence of root/enamel defects,[94] and width and thickness of KT.[92] Furthermore, the corresponding consensus report on mucogingival deformities suggested the replacement of the definition *periodontal biotype* with *periodontal phenotype*.[95]

Based on the above mentioned, an orthodontic treatment is considered to represent a risk factor for causing gingival recessions, especially in sites characterized by thin periodontal phenotypes. In a retrospective case–control study,[96] the risk for the occurrence of gingival recessions was assessed on plaster models of 100 orthodontically treated patients compared with 120 untreated controls, showing that history of treatment was associated with higher risk of recession with a significant odds ratio of 4.48.[96] The most prevalent sites for recessions were at lower incisors, supporting the hypothesis that buccal tooth movements in the presence of a thin buccal bone may increase the risks of buccal gingival recessions.[97]

Even if a systematic review[98] failed to show conclusive data on the association between orthodontic treatment and the development of gingival recessions, in clinical practice a specific patient- and site-related analysis should be carried out to assess the need of gingival augmentation before orthodontic treatment, especially at lower incisors. Furthermore, it seems that a re-evaluation of the mucogingival deformities after orthodontic therapy is needed to carefully assess the indications for additional therapies.

One of the possible indications described for gingival augmentation is the management of intrasulcularly placed restorative margins.[99] In fact, restoration margins located in the gingival sulcus require appropriate self-performed plaque control and adequate supportive periodontal maintenance.[100] Conversely, a violation of the connective tissue attachment during restorative procedures may lead to chronic inflammation with gingival recession and/ or pocket formation.[101] To date, no definitive observation seems to support a superiority of a specific finishing line in term of final recession risk.[102] Conversely, clinicians should be aware that gingival augmentation may be helpful to reduce the risk of gingival recessions, especially at teeth with very thin bordering soft tissue.

Among the possible reconstructive surgical procedures, the use of the free gingival graft is still considered the most effective technique to increase the amount of KT at both teeth and implant sites (Figure 2).[103,104] In a long-term retrospective study with a mean follow-up of 23.6 ± 3.9 years (range:18 to 35 years), Agudio et al.[105] tested the use of free gingival grafts in 47 periodontally healthy patients at 64 different sites with needs of gingival augmentation. In the same patients, contralateral sites were left untreated and followed as controls.[105] Patients were recalled every 4 to 6 months during the entire follow-up period for professional oral hygiene support. At the last follow-up, 83% of the 64 treated sites showed a recession reduction, while 48% of untreated sites experienced an increase in recession depth. Regarding the amount of KT, in the test group the values were stable over time (5.3 mm at 1 year and 4.7 mm at the last follow-up) with a significantly more coronally positioned gingival margin and mucogingival junction. On the other hand, a slight but significant reduction of KT of approximately 0.3 mm combined with a 0.5 mm increase in recession depth was reported at control sites.[105] The final observation of this long-term study documented that free gingival grafts at sites with a reduced amount of KT were effective in promoting periodontal health and gingival margin stability, thus supporting patient comfort during toothbrushing and reducing hypersensitivity of dentin.[105]

More recently, attempts to improve aesthetic outcomes and to reduce morbidity after free gingival grafting procedures have been suggested. Cortellini et al.[106] described the partly epithelialized free gingival graft for the treatment of single and multiple gingival recessions at lower incisors. The authors presented outcomes of 12 single recessions and 16 multiple recessions in a total of 19 patients. The grafts were harvested at palatal sites combining the classical free gingival and trap door harvesting approaches in order to get grafts in the desired design and composition. The epithelialized coronal part of the graft extended from the CEJ to the "ideal" position of the prospective MGJ while the apical part of the deepithelialized FGG was inserted between the alveolar mucosal flap and the retained periosteum.[106] One year after treatment excellent clinical outcomes in term of root coverage were reported. Interestingly, aesthetic outcomes were satisfactory with proper alignment of the mucogingival junction.[106]

The need of minimizing patient morbidity eliminating the donor site is a key factor to test new biomaterials for gingival augmentation. Among the proposed alternatives to FGG, acellular dermal matrix (ADM), an allograft obtained from human donor skin, has been extensively tested for both gingival augmentation and root coverage purposes. Harris[107] tested ADM versus connective tissue grafts or FGG in a randomized trial, showing comparable outcomes after 3 months of follow-up. Similarly, Wei et al.[108] tested ADM versus FGG, reporting increased gains of KT after FGG, but better aesthetic outcomes for sites treated with ADM. In a 15-years follow-up, split-mouth randomized clinical trial, Cevallos et al.[109] compared ADM with FGG. The results showed that FGG achieved higher KT gains and increased tissue thicknesses compared to ADM.[109] Improvements in the former at sites treated with FGG were detected after 6 months, supposedly due to creeping attachment, while the ADM-treated sites exhibited a shrinkage of KT but better aesthetic outcomes.[109]

Bilayer collagen matrix (BCM), as the name suggests is a xenogenic porcine bilayer collagen matrix composed of Type I and III collagen that has been extensively investigated in its use for gingival augmentation. In a total of 20 patients, Sanz et al.[110] compared BCM to CTG for gingival augmentation at both teeth and implant sites, reporting no significant differences between the 2 procedures and approximately 2 mm of mean KT gain after 6 months. BCM was associated with lower patient morbidity.[110] Similarly, McGuire et al.[111] compared BCM to FGG showing that autografts provided higher KT gain than BCM after 6 months postoperatively. Regarding the aesthetic appearance, the matrix achieved better texture and color matches compared to the FGG.[111]

Among the available technologies to reduce the invasiveness of gingival augmentation procedures, the use of living cellular constructs represents a modern and interesting approach. For the first time, an autologous cell hyaluronic acid graft was applied by Pini Prato et al.[112] for gingival augmentation. A total of 7 sites from 6 patients were treated. A small portion of gingiva (epithelium and connective tissue) was removed from each patient, placed in a nutritional medium, and sent to a laboratory where fibroblasts have been separated and cultivated. Subsequently, cells were cultured on a scaffold of fully esterified benzyl ester hyaluronic acid (HA). The obtained membrane was applied at the exposed periosteum of the treated teeth. Three months after surgery, an increased amount of KT (mean increase 2 mm) could be noticed, and the histological examination revealed a fully keratinized tissue.[112] McGuire et al.[113] tested a tissue-engineered product with neonatal keratinocytes and fibroblasts versus FGG in a large multicenter study. After 6 months, the results showed that FGG generated more KT gain than the living cell construct (LCC). LCC provided better color match and texture with the adjacent gingiva.[113] Table 1 clusters the RCT of the past 20 years, testing biomaterials for gingival augmentation. Even if the heterogeneity among studies is huge and impaired a possible meta-analysis, some conclusions could be drawn.

1. ADM and BCM are the most widely used biomaterials for the replacement of FGG in gingival augmentation procedures leading to an obvious reduction of morbidity compared with autogenous grafts, but the same time being less predictable in terms of clinical KT gain.
2. Biomaterials provided better aesthetic integration compared to autogenous grafts.
3. Assessing long-term studies (longer than 1 year), FGG treated sites showed an excellent stability with long-term improvements due to creeping attachment, while replacement biomaterials may lead to some tissue contractions.

2.3 | How do the aspects of minimal invasiveness influence the results of gingival augmentation procedures?

In the modern clinical scenario, gingival augmentation procedures should be carefully assessed considering a rigorous patient- and site-related clinical decision-making process. Additionally, an in-depth evaluation of cost–benefit ratio should be considered. When a mucogingival deficiency is characterized by both, a lack of gingival width and a gingival recession, a combined surgical treatment including root coverage and increase of KT might be indicated.

Based on the analysis of the current literature, possible indications for gingival augmentation procedures can be listed as follows:

1. Need for facilitating local access for hygiene measures in order to reduce plaque accumulation in highly compliant patients,
2. Improving patients' comfort during toothbrushing,
3. Increasing KT at sites with planned restorative or orthodontic treatments,
4. Reducing the risks of recession at sites characterized with thin periodontal phenotypes,
5. Increase of soft tissue thicknesses at prominent root areas and/or elimination of frenum pull.

TABLE 1 Randomized clinical trials comparing biomaterials for gingival augmentation

Study	Follow-up	Treatment	Patients/sites type of study	Baseline KT (mean ± SD) (mm)	Final KT (mean ± SD) (mm)	Conclusions
Wei et al. 2000[108]	6 months	ADM vs. FGG	6 patients/sites with ADM 6 patients/sites with ADM Parallel study	ADM: 0.68 ± 0.26 FGG: 0.57 ± 0.41	ADM: 3.25 ± 0.89 FGG: 6.15 ± 0.49	FGG was superior in term of KT (<0.001), even if ADM achieved better aesthetic outcomes
Harris 2001[107]	3 months	ADM vs. FGG vs. CTG	15 patients/15 sites for each 3 arms Parallel study	ADM: 0.8 ± 0.59 FGG: 0.6 ± 0.87 CTG: 0.4 ± 0.47	ADM: 4.8 ± 1.16 FGG: 4.7 ± 1.92 CTG: 4.0 ± 0.99	No difference reported among the procedures
McGuire et al. 2008[134]	6 months	BCT vs. FGG	25 patients/25 sites for each arm Split mouth study	BCT: 1.07 (SD not reported) FGG: 1.17 (SD not reported)	BCT: 2.40 ± 1.02 FGG 4.5 ± 0.8	FGG yields higher amount of KT gain. BCT group had significantly better color and texture match and subject preference
Sanz et al. 2009[110]	6 months	CM vs. CTG	10 patients/10 sites for group (please note that in the experimental sample also dental implants were included) Parallel study	CM: 0.4 ± 0.52 CTG: 0.2 ± 0.42	CM: 2.5 ± 0.47 CTG: 2.6 ± 0.96	No significant difference in terms of KT gain. CM was associated with lower morbidity
Nevins et al. 2010[155]	3 months	ECM vs. FGG	6 patients/6 sites for group Split mouth study	ECM: 0.8 ± 0.7 FGG: 1.1 ± 1.1	ECM: 2.6 ± 1.1 FGG: 6.4 ± 0.9	FGG was superior in term of KT gain. ECM achieved better color match and tissue blend
McGuire et al. 2011[113]	6 months	LCC vs. FGG	96 patients/96 sites for group Split mouth study	LCC: 1.41 ± 0.72 FGG: 1.43 ± 0.69	LCC: 3.21 ± 1.14 FGG: 4.57 ± 1.00	FGG generated more KT gain. LCC provided better color match and texture with the adjacent gingiva
McGuire et al. 2014[111]	6 months	CM vs. FGG	30 patients/30 sites for treatment Split mouth study	CM: 0.88 ± 0.61 FGG: 0.77 ± 0.68	CM: 2.92 ± 0.88 FGG: 4.42 ± 0.64	FGG provided higher KT gain. CM sites achieved better texture and color matches
De Resende et al. 2019[152]	6 months	ADM vs. FGG	12 patients/12 sites for treatment Split mouth study	ADM: 0.79 ± 0.7 FGG: 0.79 ± 0.7	ADM: 2.21 ± 0.66 FGG: 4.38 ± 0.47	FGG achieved higher KT gain and thickness. ADM showed higher shrinkage but better aesthetic outcomes
Cevallos et al. 2020[109] (sample from De Resende et al. 2019[152])	15 years	ADM vs. FGG	6 patients/6 sites for treatment Split mouth study	ADM: 0.63 ± 0.72 FGG: 0.60 ± 0.58	ADM: 2.02 ± 0.64 FGG: 5.07 ± 0.83	FGG achieved higher KT gain and thickness. FGG promote improvements compared with 6 months follow-up due to creeping attachment. ADM showed tissue contraction but better aesthetic outcomes
Ozsagir et al. 2020[156]	6 months	MN + i-PRF vs. i-PRF	33 patients/33 sites for treatment Split mouth study	MN + i-PRF 2.94 ± 1.21 i-PRF: 2.98 ± 1.1	MN + i-PRF 2.99 ± 1.22 i-PRF: 2.99 ± 1.09	MN + i-PRF provided better gingival thickness. No effect on KT width
McGuire et al. 2021[153] (sample of patients from McGuire et al. 2014[111])	6 years	CM vs. FGG	23 patients/23sites for treatment Split mouth study	CM: 0.88 ± 0.61 FGG: 0.77 ± 0.68	CM: 3.09 ± 0.85 FGG: 4.59 ± 0.69	FGG provided higher KT gain. CM sites achieved better texture and color matches. Higher patient preference for CM

Abbreviations: ADM, acellular dermal matrix; BCT, bilayered cell therapy; CM, collagen matrix; CTG, connective tissue graft; ECM, extracellular matrix; FGG, free gingival graft; i-PRF, injectable-platelet rich fibrin; LCC, living cellular construct; MN + i-PRF, microneedling + injectable-platelet rich fibrin.

There is evidence suggesting that the biomaterials ADM and BCM may be considered as possible alternatives to autogenous grafts, in order to reduce patient morbidity. However, a huge heterogeneity in terms of clinical outcomes at short-term observations and poor data regarding long-term stability are reported. Even if available data suggest higher aesthetic integration for the biomaterials compared with FGG, such findings require a careful evaluation of the inclusion of biomaterials on a routinely basis as a replacement of FGG in gingival augmentation procedures. A specific selection of biomaterials is highly recommended in each individual case, and, currently, their use should be limited to patients with specific contraindications to harvesting FGG from the palate.

Limitations of the classical FGG procedure are:

(i) The presence of a second surgical site and its related post-surgical morbidity
(ii) Possible limitations in the harvesting procedure
(iii) Adverse aesthetic outcomes due to color and texture differences compared with the adjacent tissues.

In future periodontal plastic surgery, the mentioned disadvantages of FGG might promote the use of biomaterials for gingival augmentation procedures. Nevertheless, we have to be aware that much of the policy rhetoric on new products rests not on what the product has been shown to achieve in practice but on optimistic guesses about what it would, could, or may achieve if its ongoing development goes as planned.

2.4 | Which are the current procedures and related outcomes of root coverage procedures?

2.4.1 | Surgical strategies to minimize the invasiveness of root coverage procedures

Root coverage procedures are very popular in the common practice to improve patient aesthetics and reduce root hypersensitivity.[18] The goal of the treatment is the complete root coverage with excellent soft tissue integration with adjacent sites.[44] In the past 2 decades, several attempts to minimize the extent of the surgical trauma and to favor the wound healing process have been proposed. Specific surgical steps were also introduced in order to improve clinical and aesthetic outcomes of root coverage procedures, including refinements of incisions and improved suture techniques (Figure 3).

Among the possible proposals for surgical trauma reduction, the elimination of vertical releasing incisions in coronally advanced flaps covering multiple recessions seems to be one of the most important ones.[114] Starting from the original Bernimoulin's technique,[115] Zucchelli & de Sanctis[114] have suggested a modified envelope flap with oblique submarginal incisions in the area of the interdental papillae. A combined split (at the surgical papillae)—full (from the gingival margin to the mucogingival junction)—split (beyond the mucogingival junction) thickness flap was raised-up. After a gentle root planing and the removal of the epithelium from the interdental papillae, the flap was coronally advanced and secured with a series of sling sutures.[114] This procedure allowed to improve the tropism of

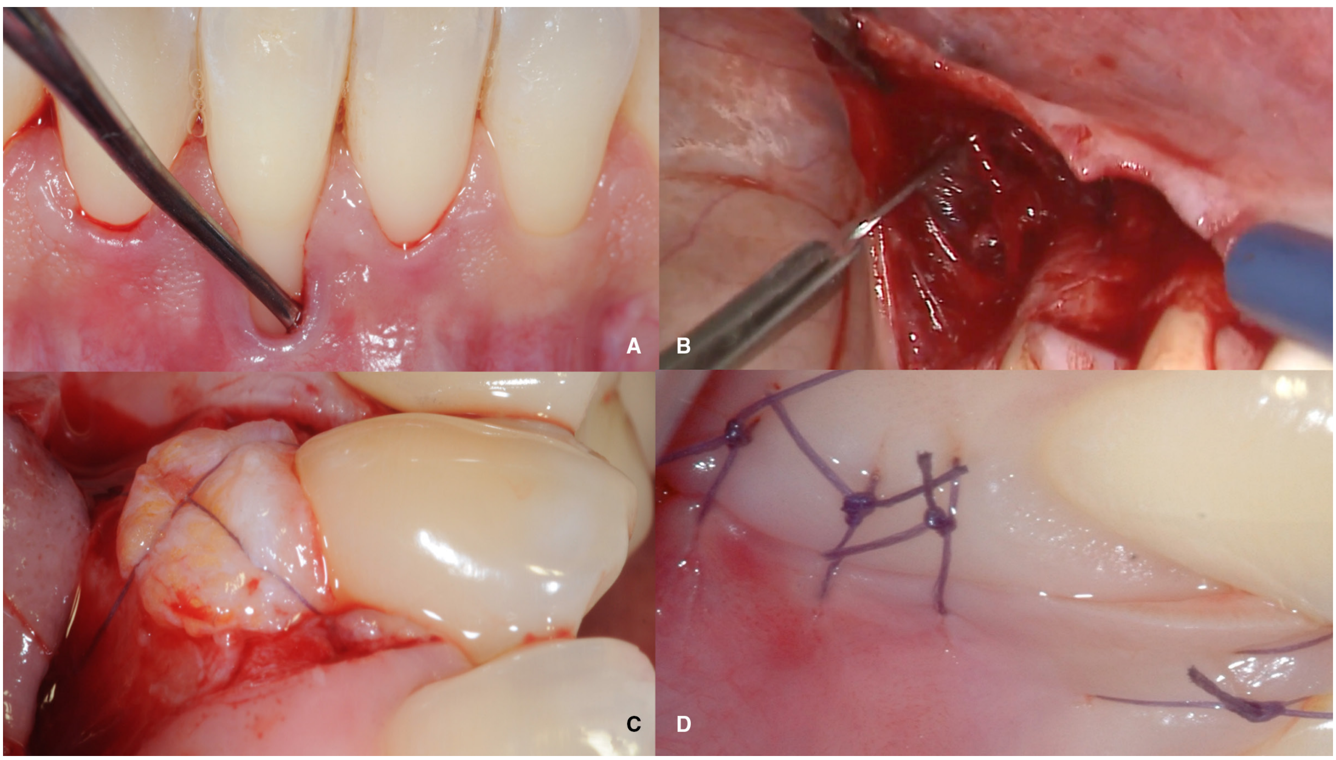

FIGURE 3 (A) Incision for tunnel procedure. (B) Supra-periosteal incision to reduce flap tension for coronally advanced flap. (C) A connective tissue graft stabilized at root dehiscence. (D) Primary closure at vertical realising incision.

the entire flap reducing surgical damage to the lateral vascular blood supply. Additionally, it helped to enhance the aesthetic outcome by the elimination of scar formations due to abstention from vertical releasing incisions. In the original case series study,[114] the authors treated a total of 73 recessions showing, at the 1-year examination, that 88% had complete root coverage. Furthermore, a statistically significant increase of KT was observed 1 year after the surgical procedure. The same group of authors compared the envelope CAF with CAF including vertical releasing incisions in the coverage of multiple recessions.[116] They randomly treated 32 periodontally healthy individuals with aesthetic demands. The results in the test group revealed more sites with complete root coverage, better aesthetic outcomes, and less surgical time compared with the control group while the percentages of mean root coverage were similar in both groups.[116]

Tunnel procedures for root coverages are frequently considered as minimally-invasive mainly for capability to reduce the surgical trauma at level of the interdental papilla (Figure 4). The technique was described as a full-thickness flap extending beyond the mucogingival junction, leaving the interdental papillae intact and followed by graft insertion,[117] although final flap characteristics could be influenced by baseline thickness. In this procedure, a delicate incision is performed at the level of interdental papillae, which are gently raised without detaching their tip.[117] The graft is then placed into the tunnel by applying a specific suture technique. In the original technique, the graft is left exposed in the area of the recession in order to promote an increase in KT.[117] The original technique was tested in a case-series study with 21 teeth showing complete root coverage in 66.7% of the treated sites. Further modifications of the tunnel procedure include the coronal advancement of the gingival margin by the help of double-crossed sutures.[118]

Possible modifications to reduce the invasiveness of periodontal plastic surgeries include the management of the connective tissue graft and its harvesting technique. Evidence showed that this procedure should be considered the gold standard when assessing root coverage outcomes at both single and multiple recessions.[4] On the other hand, harvesting grafts from palatal sites imply an increase in post-surgical morbidity and higher demands of operator skills. Several attempts to modify the harvesting procedures have been proposed in the past years. The original technique from Langer & Langer consisted of a classical trap door approach based on a split-thickness palatal flap with 2 vertical and 2 horizontal incisions.[119] Further modifications include a single mesial vertical and a single horizontal incision, a double horizontal incision or a single horizontal alone.[120-122] All these surgical efforts aimed at a reduction of the intra- and post-operative trauma and the risk to accidentally damage the palatal artery and to maintain a primary wound closure at the palatal site. Comparative studies testing different harvesting procedures are, however, inconclusive. Even if initial studies suggested that a closed wound is associated with a faster healing than the donor site of the free gingival graft,[123,124] a comparative trial by Zucchelli et al.[125] found no major differences in painkiller consumption, postoperative discomfort, or bleeding. The hypothetical explanation consisted in the assumption that deeper but covered wounds may cause a similar morbidity like open ones (secondary intention healing). More recently, Burkhardt et al.[126] assessed the self-reported pain perception after palatal graft harvesting during a 4 weeks period in 90 consecutively treated patients. The authors reported that pain was most pronounced on the first postoperative day and decreased in the subsequent days. Higher postoperative pain could be noticed for thicker grafts while increased palatal mucosal thickness before/after harvesting procedure was associated a reduction in pain perception.[126]

Among the possible modifications regarding graft dimension, modern literature has shown that graft dimensions similar to the extension of the dehiscent area under the CAF are associated with better aesthetic outcomes compared to grafts extending the dehiscent area.[127] Furthermore, a positive correlation between KT thickness and the use of CTG in both single[66] (Cairo 2020) and multiple recession treatment[128] has been reported. In fact, when a CTG is applied at recessions with minimal mucosal thickness (<0.8 mm) a higher probability of complete root coverage and better aesthetic outcomes could be noticed, while a CTG fixed at sites with well represented KT (thickness > 0.8 mm) did not bring an adjunctive clinical benefit, but ended in higher morbidity and less aesthetic outcomes compared with CAF alone.[66,128] These evidences suggest that a proper site-specific evaluation before CTG application should be performed especially in patient with high aesthetic demands[129] (Figures 5 and 6). Such site- and patient-related clinical decisions might significantly reduce the morbidity of the patient, especially in multiple recession treatments.

2.4.2 | Allografts and replacement biomaterials for minimal invasive root coverage

A number of different allografts and different replacement biomaterials has been suggested in periodontal plastic surgery to promote root coverage under the CAF for both single and multiple recessions and to reduce the need of a second surgical procedure. In the 1990s, the use of barrier membranes under CAF for single recession treatment was a very popular procedure. Meta-analysis showed that such procedures were associated with a huge variability of root coverage outcomes (mean root coverage of 48%–87%) and a very high incidence of complications, especially for non-resorbable barrier membranes, that reduced the clinical benefits.[4] That's why, today, barrier membranes for root coverage are obsolete in the clinical practice. Among the proposed modern biomaterials, enamel matrix derivatives, acellular dermal matrix (ADM) and collagen matrix (CM) are probably the most intensively investigated ones in the current literature.

Enamel matrix derivatives (EMD) are extensively used to obtain predictable periodontal regeneration for infrabony defect.[130] EMD plus CAF has been applied for root coverage procedure as well, supported by histological findings documenting the formation of new cementum in the apical part of the dehiscence with inserting

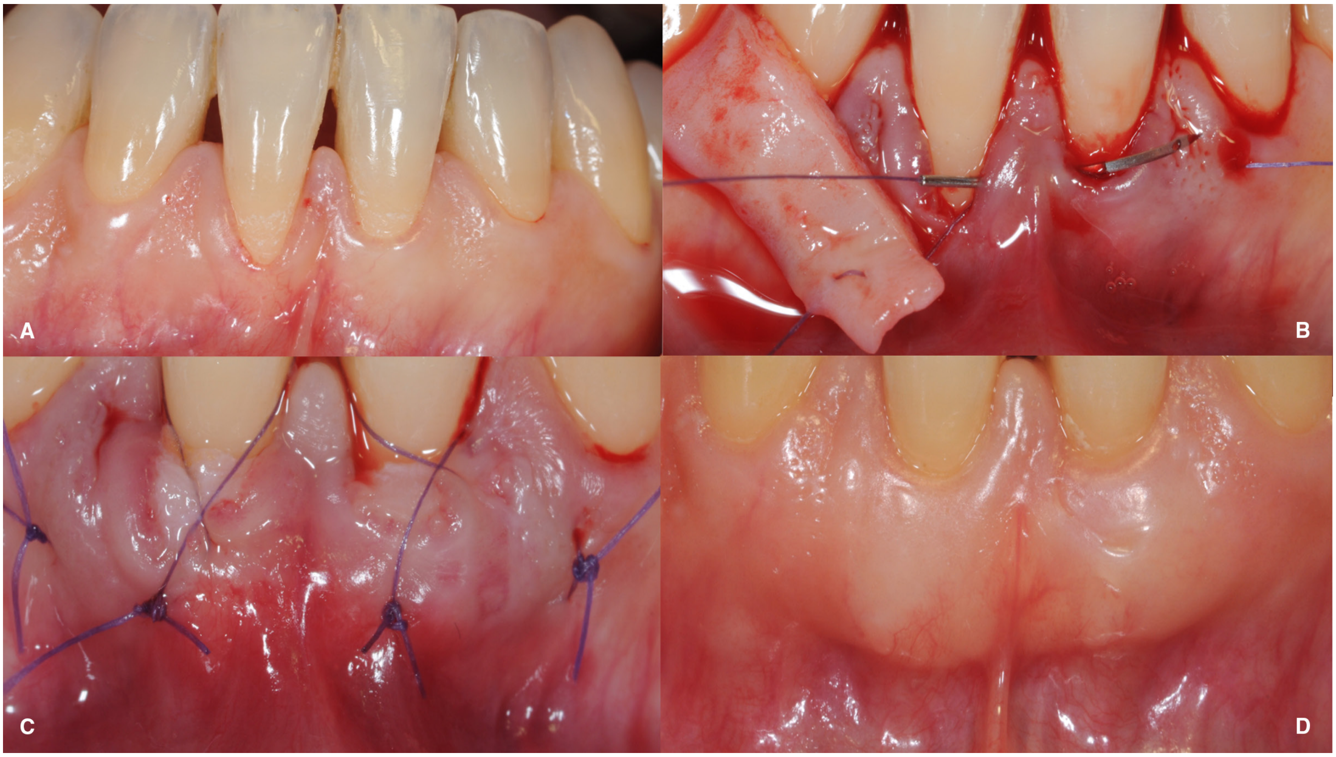

FIGURE 4 (A) Baseline RT2 recessions at central lower incisors. (B) A tunnel procedure with connective tissue graft was performed. (C) The graft was stabilized into the tunnel. (D) Soft tissue healing 6 months after surgery with full root coverage and increase in KT.

collagen fibers.[131] A meta-analysis on single recession treatment showed that EMD+CAF yielded better root coverage outcomes (mean root coverage 84%–94%) than CAF alone leading to minimal, even if significant, final increase in KT gain.[44] Very few studies assessed the long-term outcomes of EMD at single recessions. McGuire and Nunn[132] reported the long-term follow-up (10 years) including only 9 patients with paired recessions treated comparing EMD+CAF with CTG+CAF. The authors described the excellent stability of the initially achieved outcomes in the long-term evaluation without significant differences between the 2 techniques. Less information is available on the use of EMD for multiple recession treatment. An RCT by Cordaro et al.[133] tested multiple CAF with or without EMD in 10 patients with bilateral recessions. At the 2-year follow-up no significant differences were detected in terms of root coverage outcomes. Similar observations were provided by studies for multiple recession treatment applying tunnel procedure and CTG.[134,135]

Root coverage combined with acellular dermal matrix was tested in different clinical trials on both single and multiple recessions. A systematic review for single recession treatment showed a huge variability in the clinical outcomes with root coverage ranging from 50% to 97%.[44] A similar heterogeneity could be detected for multiple recession treatments, even if there was a trend for improved outcomes especially when treating recession with a very thin phenotype.[136,137] In a randomized trial, Ahmedbeyli et al. tested the aesthetic and clinical outcomes of ADM plus CAF for multiple-recession defects in 22 patients with 55 RT1 recessions.[136] At the 1-year follow-up, no significant difference was detected between the groups in terms of sites with complete root coverage.[136] A certain degree of relapse of gingival margins was described in long-term studies for ADM treated sites. Tavelli et al.[138] investigated long-term outcomes of ADM combined with multiple CAF or tunnel in multiple adjacent gingival recessions. A total of 19 of the original 24 patients were followed for the duration of 12 years. At the final follow-up a high degree of recurrence of recessions was reported in both groups, with a significant reduction of sites with complete root coverage between 52% and 27% in CAF group and from 51% to 29% in the tunnel group.[138] KT width ≥2 mm and gingival thickness ≥1.2 mm at 6-months were 2 predictors for stability of the gingival margin.[138] Considering the heterogeneity of the clinical outcomes and legal restrictions in using dermal matrices in different countries, ADM seems to have a limited applicability in modern root recession coverage.

The possible benefits of CM under a coronally advanced flap for root coverage have been tested in a histologic study, revealing that the porcine collagen matrix was able to promote soft-tissue regeneration and new attachment in experimental recessions in the dog model.[139] Burkhardt et al.[68] tested the role of CM in improving early flap stability. Sixty bone dehiscence defects were treated in Beagle dogs with flaps alone or in combination with CTG or CM. Subsequently, a tensile force was applied after suture removal at 1, 3, 7, and 14 days postoperatively. Flap resistance to tearing was highest in the CTG group, while minimal at the interface flap-root without interposition of a CTG or CM.[68] The use of CM improved flap stability compared to flaps without interpositioned CTG or CM

FIGURE 5 (A) Multiple RT1 recessions in frontal maxillary area. (B) A large flap from right cuspid to left first premolar was performed. A tunnel was done at the interdental papilla between the central incisors. (C) Right side of the surgery. (D) Left side of the surgery.

FIGURE 6 (A) A single connective tissue graft was placed only at right cuspid (deeper recession and minimal KT). (B) The flap was coronally advanced. (C) Soft tissue healing one-year after surgery with full root coverage at all treated teeth.

but lower than CTG at every observation. This increase in flap resistance to disrupting forces was much more pronounced for CTG than for CM. The benefit of CM in combination with CAF has been documented in different trials.

Jepsen et al.[140] tested in a multi-center split-mouth trial on 90 recessions in 45 patients CAF + CM or CAF alone. After 6 months, there was no significant difference in terms of root coverage outcomes. When limiting the analysis to deeper (≥3 mm) sites, recessions treated with CM showed higher root coverage and more KT gain.[140]

Similarly, McGuire reported outcomes comparing CM with CTG under CAF for single recession treatments.[141] At 1 year, mean root coverage was 88.5% for CM + CAF and 99.3% in CAF + CTG. KT width was similar for both therapies.[141] A large multicenter study (187 patients with 485 recessions in 14 centers) tested CM or CTG under CAF.[142] Surgeries without a harvesting procedure were significantly shorter in the duration (approximately 15 min) and perceived as less traumatic by patients, associated with less postoperative morbidity.[142] The probability of complete root coverage was significantly higher in the CTG group (75% vs. 50%). Better aesthetic outcomes were reported for CTG treated sites.[143] A clinical case of multiple recessions treated with CAF and CM is shown in Figure 7.

2.4.3 | Clinical outcomes for single and multiple recessions treatment and related morbidity

An extensive systematic review showed that CAF procedures are predictable techniques to obtain root coverage and the best documented recession coverage techniques in clinical trials.[44] CAF alone has become very popular in the past 2 decades when a number of clinical studies has demonstrated its reliability for root coverage purposes. It appears that an "adequate" amount of baseline KT, along with the control of important surgical related-factors are specific prerequisites for predictable root coverage outcomes.[129] The reported outcomes 6 months after surgery were a mean root coverage of ~72% and a probability of complete root coverage of ~39%.[44] Baseline recession depth[144] and loss of interdental attachment[67] reduced the probability of complete root coverage. Among the combined CAF techniques, adding a CTG was the most effective modification to obtain complete root coverage at single recessions, with a mean root coverage of ~85% and a probability of complete root coverage of ~52% of all treated sites.[44] Additionally, its efficacy was supported by the capability in augmenting final KT in width and thickness.[44] However, long-term studies have documented a certain degree of recurrence of recession for sites treated with CAF.[145] Tavelli et al.[146] presented a network meta-analysis to simultaneously compare different surgical approaches in the long term. Sixty RCTs with a total of 2554 gingival recessions and 1864 patients were included. Results clearly demonstrated that only CTG-based procedures were effective in maintaining the stability of the gingival margins over time.[146] Baseline recession depths and KT width at the earliest postoperative recall were predictors for the stability of the gingival margins. In addition, a geographic center effect was described, thus suggesting that heterogeneity in supportive periodontal care setting may influence the stability over time.[146,147]

Multiple gingival recessions treatment is usually more challenging since several factors are interconnected with each other in the surgical scenario. Under these conditions, the amount of donor tissue that can be obtained from the palate may not be adequate for the treatment of all buccal recessions. A systematic review with a Bayesian network meta-analysis showed that modified CAF and tunnel approaches in association with CTG yielded the highest percentages of complete root coverage.[148] Similarly, long-term trials showed higher stability after 5 years of observation for CTG-treated sites compared with CAF alone.[149,150] This body of evidence regarding the use of CTG for multiple recession treatment should be carefully assessed in order to have a proper management of intra-surgical difficulties and post-surgical morbidity.

Interestingly, attempts for minimizing morbidity in applying CTG for multiple recessions are present in literature. In a randomized clinical trial Cairo et al.[128] compared the clinical efficacy of coronally

FIGURE 7 (A) Multiple RT1 recessions from lateral incisor to the first molar. (B) A multiple coronally advanced flap was performed: a collagen matrix was secured at dehiscence at level of premolars. (C) The flap was coronally sutured. (D) Soft tissue healing 6 months after surgery with full root coverage and increase in KT thickness.

advanced flap (CAF) with or without CTG for the treatment of multiple adjacent gingival recessions in the upper arch. A total of 32 patients with a total of 74 gingival recessions were randomly allocated to the 2 groups.[128] When considering the evaluation of the surgical procedure and post-operative period (10 days) in terms of morbidity, patients allocated to CTG group showed higher intensity of post-surgical discomfort and higher intake of anti-inflammatory tablets than controls, thus confirming the higher morbidity of CTG procedures at patient level. At the 1-year follow-up, the use of CTG was associated with better root coverage outcomes and KT gain than CAF alone. Interestingly, CTG represented an effective benefit only when applied at recessions with minimal mucosal thickness (<0.8 mm) while when a CTG was applied at sites with well represented KT, CAF alone achieved better clinical and aesthetic outcomes.[128] A similar approach was used in a prospective trial by De Sanctis et al.,[151] reporting about successful treatment of a total of 93 recessions in 23 patients, adding CTG only at sites characterized by minimal KT amounts or extended recession depths.

Based on the available scientific evidence in periodontal plastic surgery, it seems to be feasible that the invasiveness after surgical interventions can be reduced by using CAF without vertical releasing incisions, modified tunnel approaches and a strict indication of harvesting CTG.

2.5 | How do the aspects of minimal invasiveness influence the results of root coverage procedures?

In a historical perspective, the free gingival graft was considered the gold standard procedure for root coverage in the 80s, when aesthetics were not a target of treatment and the loss of interdental tissue was supposed as the most important clinical limitation in obtaining complete root coverage. Conversely, modern root coverage procedures should be aiming at improvement of aesthetics. This, in turn, implies that the current primary treatment goal is focusing on excellent soft tissue integration in terms of color match, mucogingival junction alignment and absence of scar tissue and not only the quantity of tissues covering the roots. In this respect, proper flap and graft handling have significantly improved the predictability of outcomes at recessions with loss of interdental attachment.[129] Such a shift of paradigms has been substantially influenced by the concepts of minimal invasiveness in periodontal surgery. In fact, critical surgical elements such as flap tension and thickness paired with the concept of wound stability are routinely included in pre- and intraoperative decision making in order to promote soft tissue healing. This body of knowledge has significantly contributed to improve techniques not only in terms of predictability but also for reduction of morbidity.

In the modern clinical scenario, there is an upward tendency to treat multiple gingival recession in 1 surgical session instead of staged single interventions.[114] This was enabled through the high predictability of modern procedures that incorporate the aspects of minimal invasiveness, including elimination of vertical releasing incisions and proper separation of the alveolar mucosa from muscle insertion in the split-thickness part of the flap. In addition, there is an ongoing shift of indications in the use of connective tissue graft, that is unanimously considered as the gold standard procedure. In fact, recent clinical trials[66,151] suggested a proper site-specific use of CTG, mainly indicated in case of recessions with very thin flap. The use of the graft in case of thick flaps does not change the quantity of final root coverage and reduces aesthetic outcomes, implying higher morbidity at palatal site.[66,128] To achieve the aforementioned goals in the clinical practice, it is important that the use of oversized CTG submerged under multiple CAF or tunnel procedures is limited to cases of multiple recessions with poor KT widths where the increase in soft tissue thickness is the primary treatment target instead of aesthetics. There is limited evidence that certain biomaterials (mainly EMD and CM) may promote root coverage when placed under CAF.[44] Under specific circumstances, the expected outcomes may be close to the ones with CTG but showing less morbidity than combined graft procedures. There is no doubt that all aspects of a minimally invasive treatment concept have to be respected when using biomaterials in soft tissue regeneration.

Based on our initial definition of minimal invasiveness in periodontal plastic surgery, there is clear evidence that a modification of conventional techniques aiming at a reduction of intra- and post-operative trauma, increases the predictability and outcomes of the surgical interventions and improves the patient-related outcomes in terms of morbidity and satisfaction. From a clinical perspective, the inclusion of minimally-invasive concepts seems to be paramount in modern periodontal plastic surgery.

3 | CONCLUSIONS

A concept of minimal invasiveness in gingival augmentation and root coverage procedures should be based on the inclusion of technical and nontechnical aspects, the latter comprising clinical decision-making, the recognition of the predominant cognitive biases and the importance of communication between the patient and the clinician. A continuous technical skills training builds the basic prerequisite to steadily improve hand and finger dexterity and to refine tactile perception at the interface between the surgeon's hand and the instrument handle.

A number of clinical trials has shown that it is possible to obtain excellent clinical outcomes in terms of quantity and quality of the reconstructed soft tissues by using minimally-invasive approaches. Such findings clearly support the necessity to establish concepts of minimal invasiveness in the clinical theater when it comes to gingival augmentation and root coverage procedures in order to achieve the above-mentioned goals.

Among the influencing factors, the most predominant ones are (1) the control of flap tension, (2) a proper flap design without unnecessary incisions, (3) graft dimensions limited to the site-specific needs, and (4) a wound stability that promotes clinical functional and aesthetic outcomes.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest related to this manuscript.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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