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REVIEW ARTICLE

Complications and treatment errors in root coverage procedures

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1 | INTRODUCTION

Periodontal plastic surgery is a scientific term introduced to describe a set of surgical procedures, including root coverage techniques.[1] The latest consensus in periodontics[2] pointed out the main indications for the treatment of gingival recession defects and the need to bear in mind patient-centered outcomes when selecting a specific surgical procedure. Esthetics, root hypersensitivity, oral hygiene improvement, and carious/noncarious cervical lesions associated with gingival recessions are considered the principal indications for the treatment.[2] Over the years, several techniques have been proposed to reach complete root coverage, meaning the gingival margin's location is slightly coronal to the cemento–enamel junction with no residual probing depth, together with no detectable inflammation and a harmonic soft tissue and color integration.[3] The coronally advanced flap (alone or combined with a connective tissue graft, enamel matrix derivative, and collagen matrix) and tunnel techniques effectively pursue gingival recession resolution.[4–8] By their nature, surgical procedures could be correlated to a risk of developing intra- and postoperative complications, including pain, bleeding, swelling, and infection, which are a matter of concern to the practitioner and the patient.[9] Furthermore, professional errors in treatment planning and execution may contribute to the occurrence of complications and side/adverse events, leading to a detrimental effect on the foreseen treatment results.

This review will focus on treatment errors, complications, or side/adverse effects that may arise during the different therapeutical phases (presurgical, intrasurgical, and postsurgical) of root coverage procedures and how to prevent and manage these issues.

2 | PRESURGICAL PHASE

A comprehensive assessment of a patient's current health status, history of the disease, and risk characteristics are essential for determining the periodontal diagnosis and prognosis of the dentition and crucial for the development of a logical treatment plan in order to achieve the desired results.[10] The term treatment planning implies complete knowledge of: the patient's requests, the precise diagnosis, the etiology of the problems, the prognoses, and the possible management options to avoid/reduce treatment errors. Establishing a comprehensive view of the problem(s) and patient compliance is mandatory before starting any treatment. In fact, even under the best set of circumstances, the predetermined endpoints may not be reached due to underestimation of risk factors or medical diseases that could interfere with the surgical treatment (Figure 1).

2.1 | Dietary and herbal supplements consumption

Root coverage procedures, like any periodontal surgery, may be affected by systemic diseases, medication intake, and bad habits, potentially resulting in impaired wound healing and complications.[11] Treatment errors and complications in periodontal therapy in a

Claudio Mazzotti and Ilham Mounssif contributed equally.

[Correction added on August 10, 2023, after first online publication: The affiliation for the author Giovanni Zucchelli has been updated.]

FIGURE 1 Presurgical phase

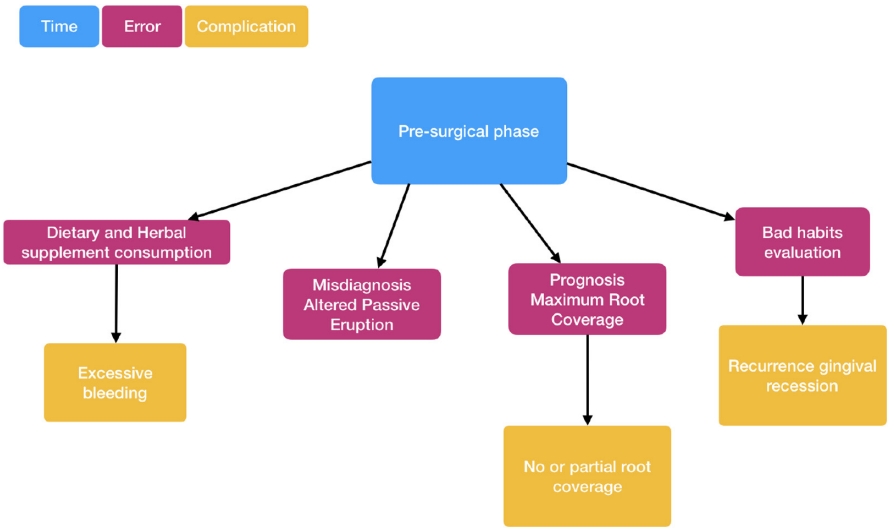


TABLE 1 Bleeding effects of herbal and dietary supplements

Antiplatelet properties	Anticoagulant properties	Antiplatelet and anticoagulant properties	Interfering with blood clotting by other mechanisms
Aloe	Chamomile	Dong quai	Coenzyme Q10
Cranberry	Fenugreek	Evening primrose	Flaxseed
Feverfew	Red clover	Ginseng	Grapefruit
Garlic		Vitamin E	Green tea
Ginger			Oregano
Ginkgo			Saw palmetto
Glucosamine			
Lycopene			
Magnesium			
Meadowsweet			
Omega-3 fish oil			
Selenium			
Turmeric			
Vitamin A complex			
White willow			

medically compromised patient will be discussed in Cho et al's[12] review in this volume.

Regarding systemically healthy patients, we would like to draw attention to a topic that has been taken into account in general surgery but scarcely investigated in dentistry: dietary and herbal supplement consumption. The US Food and Drug Administration[13] defined dietary and herbal supplement as a product taken orally that contains a "dietary ingredient" intended to supplement the diet. Dietary and herbal supplements do not need a medical prescription and are poorly regulated; these factors have created a positive environment for growth in the market, and their consumption is increasing globally.[14] Because these popular products contain "natural" ingredients, most consumers perceive them to be safe. However, there is rising evidence of health risks associated with these remedies in the perioperative population.[15–17] Several papers[16,18–21] have documented interaction effects mainly correlated with the level of sedation and bleeding tendencies. It has been reported that some herbal medicines[22] and nutrients[23] included in the dietary supplements have been shown to possess the potential to interfere with blood clotting, leading to risk of excessive intra- and postoperative bleeding (Table 1).

In light of these issues correlated with dietary and herbal supplements, the American Society of Anesthesiologists and the American Academy of Orthopedic Surgeons has introduced recommendations to discontinue the intake of specific herbal products for up to 2 weeks before surgery for all patients requiring surgery.[24] Although this approach could be considered excessive, the lack of knowledge regarding the identity, concentration, and pharmacokinetics of the active principles in most dietary and herbal supplements justifies a restrictive policy because of the risks and benefits that may be involved.[25]

Like in other medical-surgical branches, more awareness should be promoted in surgical dentistry in order to predict the potential risk of bleeding in dental patients consuming dietary and herbal supplements. This is especially true whenever there is concomitant administration of blood-thinning or analgesic drugs, such as certain nonsteroidal anti-inflammatory drugs (eg, ibuprofen) prescribed for pain relief.[22] Therefore, clinicians' and patients' acquisition of improved knowledge about dietary and herbal supplements, recording their use in the patient medical history, and evaluating discontinuing the consumption during the perioperative period may predict and prevent bleeding complications.

2.2 | Diagnostic and prognostic errors

The principal elements that lead to treatment errors are associated with an incorrect diagnosis, nonidentification of the etiology, and lack of knowledge in terms of prognosis of gingival recession treatment. Gingival recession is defined as displacement of the soft-tissue margin apical to the cemento–enamel junction.[26] The first mistake is strictly correlated to the definition itself: in order to diagnose a gingival recession, the cemento–enamel junction must be identified and the root surface exposed to the oral cavity. Clinically, gingival recession determines an elongated appearance of the affected tooth when compared with the adjacent teeth. A similar condition that may mislead an inexperienced practitioner into diagnosing a gingival recession is when the teeth adjacent to the "elongated tooth" are affected by the altered passive eruption (Figure 2). The latter is a clinical situation in which the relationship between teeth, alveolar bone, and soft tissues produces an excessive gingival display, resulting in apparently short clinical crowns.[27] Therefore, in the said scenario, the "elongated tooth" is actually a healthy tooth with a physiologic relationship between soft tissue margin location and cemento–enamel junction. For this reason, clinicians must have full knowledge of altered passive eruption and its clinical and radiographical diagnosis.[27]

In the literature, two main classification systems of gingival recessions are available[28,29] for prognostic evaluation of root coverage. According to said classifications, Miller class I/II and RT1 recessions are expected to achieve complete root coverage outcomes, whereas in Miller class III/RT2 and Miller class IV/RT3 only partial and no root coverage can be accomplished, respectively. Still, it may be possible to improve the limited root coverage outcomes if the factors affecting maximum root coverage are appropriately evaluated and modified; that is, loss of interdental papilla height, presence of tooth rotation, buccal malposition, tooth extrusion (with or without occlusal abrasion), and a cervical abrasion defects.[30,31] Taking this into account, a method has been proposed to predetermine the maximum level of root coverage: by calculating the ideal vertical dimension of the interdental papillae of the tooth with the recession defect, it is possible to predetermine the position of soft tissue margin after root coverage surgery,[30,32] allowing the identification and reshaping (with composite restoration) of a new "clinical" cemento–enamel junction whenever the anatomic cemento–enamel junction is no longer clinically visible or when the ideal conditions to obtain complete root coverage are not present (Figure 3). Furthermore, it is crucial to identify the need to modify the soft tissue phenotype on a case-by-case basis and for each individual tooth being treated in cases of multiple adjacent recessions in order to achieve the expected root coverage and to ensure the stability of the results over time.[33,34]

In addition to the soft tissue assessment, it is mandatory to also take into consideration hard tissue discrepancies (ie, noncarious cervical lesions) associated with gingival recession defects.[35] Pini-Prato et al[36] introduced a classification system of dental surface defects in areas of gingival recession, based on the presence (A) or absence (B) of identifiable cemento–enamel junction and presence (+) or absence (–) of dental surface discrepancy caused by abrasion (step), thus resulting in four classes: A+, A–, B+, and B–. After having evaluated 1010 exposed root surfaces associated with gingival recessions, they found that 14% belonged in Class A+, 46% in Class A–, 24% in Class B+, and 15% in Class B–.

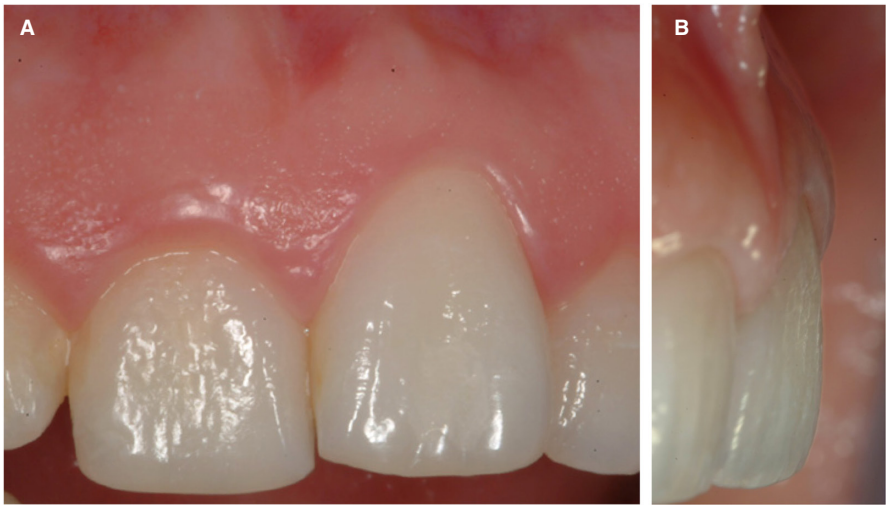


FIGURE 2 A, Misdiagnosis of gingival recession in the presence of an "elongated tooth" (left maxillary central incisor) adjacent to a "short" tooth affected by the altered passive eruption (right maxillary central incisor). B, Tooth profile shows a physiological crown length without evidence of cemento–enamel junction or root exposure, which are prerequisites for diagnosing gingival recessions.

According to the mentioned study, approximately 50% of gingival recession defects presented in association with root surface lesions, typically in the form of noncarious cervical lesions,[37] therefore creating combined defects. This implies the need for specific treatment protocols[38,39] that include a mixed restorative-surgical approach in order to achieve the desired outcomes in terms of root coverage and esthetics. In this respect, Zucchelli et al[39] presented a decision-making process for treating noncarious cervical lesions associated with gingival recessions based on the topographic relationship between the level of maximum root coverage and the extent of the noncarious cervical lesions (Figure 4). The comprehensive assessment of the maximum root coverage achievable for every single case and the restoration of associated noncarious cervical lesions can prevent the occurrence of incomplete root coverage, unaesthetic appearance (for patients and clinicians), and inadequate emergence profiles that would inevitably hinder proper oral hygiene practices[39] (Figure 5).

2.3 | Bad habits evaluation

Bad patient habits that could affect the outcome of root coverage procedures should also be identified during the presurgical evaluation. Particular attention should be paid when evaluating toothbrushing habits and identifying smokers. An "improper" toothbrushing method has been proposed as the most critical mechanical factor contributing to the development of gingival recessions.[40–44] Recent systematic reviews[44,45] pointed to an association between toothbrushing and recession, although definitive evidence is lacking. Among the most frequent factors associated with gingival recession, duration and frequency of toothbrushing, brushing force, frequency of toothbrush renewal, bristle hardness, and toothbrushing technique (horizontal or scrub method) were identified. Hence, during the examination phase, efforts should be concentrated on detecting bad toothbrushing habits and on their modification through motivation and proper oral hygiene instructions. It has also been suggested that soft tissue inflammation plays a role in gingival recession development, especially at sites with a thin periodontal phenotype and difficulty in home oral hygiene.[43,46,47] Moreover, as happens with other periodontal surgical procedures, poor oral hygiene is a factor that negatively affects the success of root coverage techniques.[48]

Smoking is a patient-related factor that can influence the wound healing process due to the alteration of gingival tissue vascularization, immune and inflammatory responses, and healing potential of the periodontal connective tissues.[49,50] Scientific evidence showed that smokers might benefit from root coverage procedures since no difference in root coverage outcomes has been reported between smokers and nonsmokers when coronally advanced flap alone was adopted for recession treatment.[6] However, a recent meta-analysis[6] found that subepithelial connective tissue graft–based techniques do not provide the same treatment effect as that achieved in

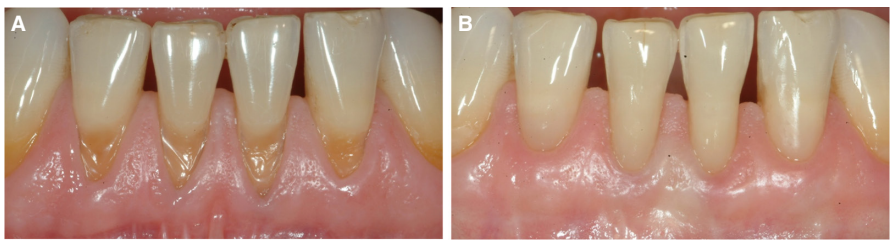


FIGURE 3 A, Gingival recessions and noncarious cervical lesions affecting the mandibular incisors. The presence of reduced height of interdental papillae decreases the chance to achieve a complete root coverage, and for this reason the "new clinical cemento–enamel junction" should compensate the interdental soft tissue loss. B, Clinical situation after 3 mo revealing the perfect root coverage and soft tissue integration thanks to a combination of restorative approach (treatment of noncarious cervical lesions reshaping the clinical cemento–enamel junction) and coronally advanced flap plus connective tissue graft

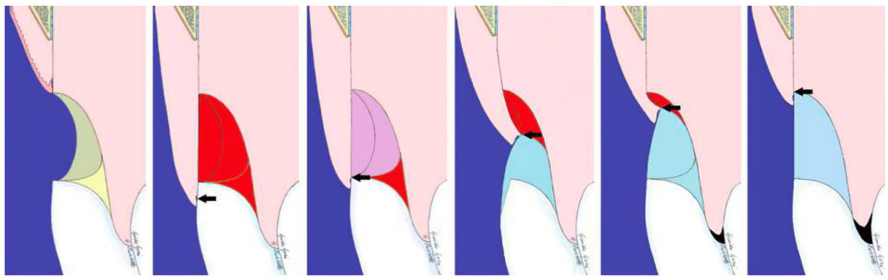


FIGURE 4 Decision-making process for treating noncarious cervical lesions associated with gingival recessions. The depth and location of the noncarious cervical lesions together with the maximum root coverage achievable determine the proper approach (surgical, restorative-surgical, or restorative approach). The chart has already been described by Zucchelli et al.[39] Reproduced with permission from John Wiley and Sons

FIGURE 5 A, Multiple gingival recessions associated with noncarious cervical abrasions affecting maxillary teeth. B, Noncarious cervical lesions have been restored using composite according to the evaluation of the maximum root coverage. C, D, Envelope coronally advanced flap plus connective tissue graft for the treatment of multiple gingival recessions. E, Clinical photograph showing the postoperative situation immediately after surgery. F, Clinical situation after 3 mo revealing a successful outcome in terms of root coverage and soft tissue integration. G-I, Comparison between baseline situation (G), after the restoration of noncarious lesions (H) and the final outcome at 3 months (I)

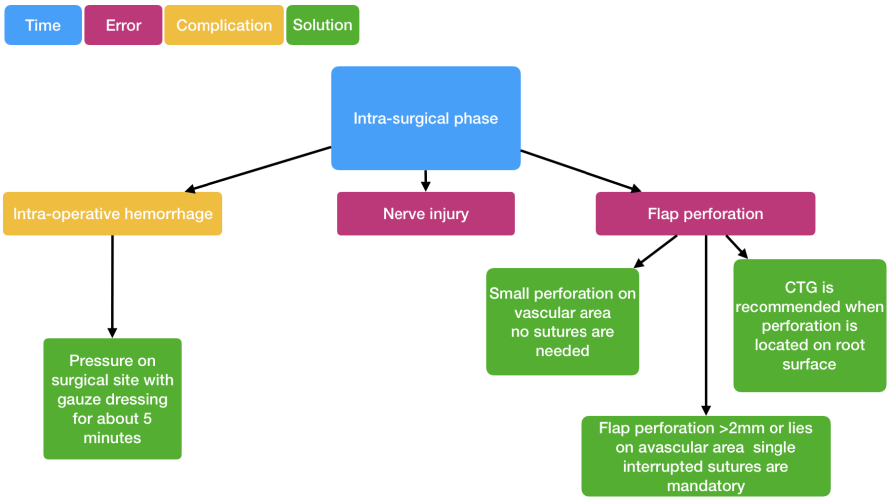


FIGURE 6 Intrasurgical phase. CTG, connective tissue graft

nonsmokers, reporting an additional 17.5% of mean root coverage and a superior number of sites achieving complete root coverage in nonsmokers (risk ratio 0.36) compared with smokers.

All of these considerations stress the importance of an accurate medical examination and a diagnostic process that takes into account possible etiologic factors and evaluates the presence of bad

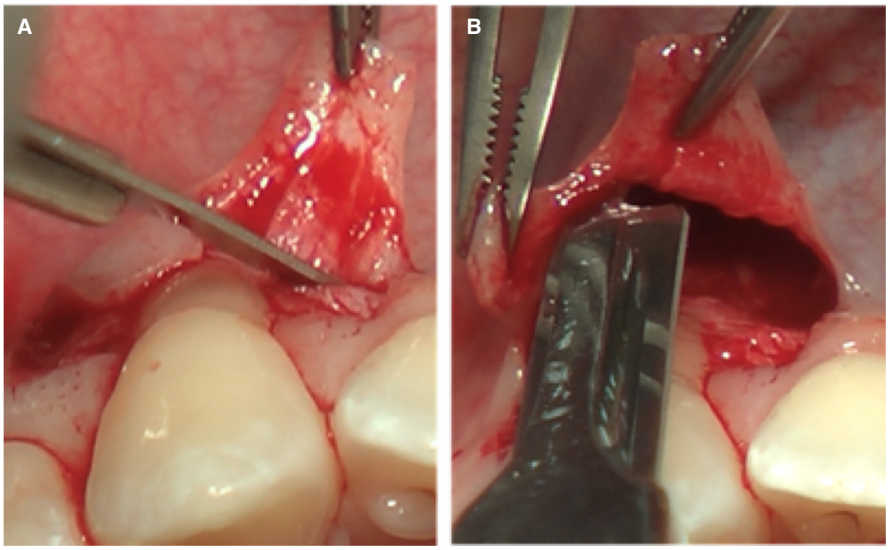


FIGURE 7 A, Deep split-thickness incisions adequately made using the blade parallel to the periosteum, sufficient to separate muscle insertions from the underlying bone. B, Performing the "superficial" incision by positioning the blade parallel to the external mucosal surface and detaching muscle insertions from the inner aspect of the flap. The correct accomplishment of the previous incisions avoids damaging greater vessels located in the submucosal layer and muscular structure, reducing the occurrence of "excessive bleeding"

habits and to avoid treatment errors that may contribute to the occurrence of complications and side events with detrimental effects on the expected treatment outcome.

3 | INTRASURGICAL PHASE

The performance of root coverage procedures requires varying levels of proficiency regarding technical knowledge, practical skill, and abilities in addition to professional experience. A clinician's lack of theoretical knowledge and/or practical experience might represent the most frequent source of accidental errors during the treatment; consequently, a less experienced operator is responsible for a greater number of errors and complications during the surgical procedure—which could alter the course of wound healing to some extent (Figure 6).

3.1 | Intraoperative hemorrhage

As happens with other periodontal techniques, intraoperative bleeding is commonly associated with root coverage procedures and requires proper management, especially when it appears excessive and uncontrolled (primary hemorrhage). The question is, what does "excessive bleeding" mean? To the best of our knowledge, no studies have reported on the incidence of "excessive" intraoperative bleeding or given threshold values to describe it. Few studies have investigated the amount of blood loss during periodontal surgery (open flap debridement and regenerative techniques); those that did have reported a range from 0.5 mL up to 145.1 mL of blood loss, influenced by the preoperative intake of nonsteroidal inflammatory drugs and the epinephrine concentration in the local anesthetic.[51–54] The reported volumes would point out that blood loss during periodontal surgical procedures is relatively minimal compared with other procedures in general surgery.[54]

Regarding root coverage surgeries, uncontrolled excessive bleeding is unlikely and limited to cases of inappropriately performed harvesting procedures (ie, greater palatine artery injury; see the chapter about complications of palatal soft tissue harvesting by Tavelli et al[55] in this volume). In spite of this, it is important to know how to reduce and handle intrasurgical bleeding.

The control of bleeding starts before the incision is made, with the injection of topical anesthetic agents for intraoperative pain management combined with a vasoconstrictor in the surgical site. Epinephrine is the one most commonly used;[56] in healthy patients, its maximum dose is 0.2 mg (11 carpules at a 1:100 000 concentration).[57] A decrease in gingival blood flow should be apparent within 5 minutes after epinephrine injection.[58] For patients undergoing periodontal surgery, it has been shown that anesthetic formulations containing 4% articaine and epinephrine (either 1:100 000 or 1:200 000) provided excellent intrasurgical pain control; the 4% articaine and 1:100 000 epinephrine formulation had the additional therapeutic advantage of providing better visualization of the surgical field and less bleeding.[53]

An adequate presurgical examination of medical history (assumption of anticoagulant medications, nonsteroidal anti-inflammatory drugs, and dietary and herbal supplements) might help to reduce unexpected intraoperative bleeding. However, despite a favorable medical history, increased bleeding can also result from errors made when carrying out flap incisions. For this reason, it is essential to perform the split-thickness incisions adequately: A limited "deep" incision is made, using the blade parallel to the periosteum, to separate muscle insertions from the underlying bone just enough to allow performing the "superficial" incision by positioning the blade parallel to the external mucosal surface and thus detaching muscle insertions from the inner aspect of the flap. The latter incision terminates when the flap's coronal mobilization is considered "adequate," meaning the flap's marginal portion can passively reach a level coronal to the cemento–enamel junction[59] (Figure 7). The correct execution of the previous incisions avoids damaging larger vessels located in the submucosal layer and the muscular structure.

It is crucial to perform the split-thickness incisions at the beginning of the surgery (immediately after full-thickness flap elevation), and afterwards bleeding is controlled (even if particularly intense) by keeping a gauze in place to protect the flap until the time of the suture. If, on the contrary, this surgical step is performed towards the end of the procedure, delayed bleeding may appear after flap closure or even after patient discharge (reactionary hemorrhage that occurs within 24 hours). Intraoperative hemostasis is achieved by applying pressure to the surgical site for 3-5 minutes with a gauze dressing, either dry or soaked in hemostatic agents.[60] Among these, tranexamic acid is one of the most frequently used and it works by inhibiting plasminogen action and reduces the fibrinolytic activity of the early formed hemostatic clot. Despite being widely used, topical application of tranexamic acid (irrigation, soaked gauze), still lacks evidence for efficacy in the control of intra- and postoperative hemorrhage.[60] Alternatively, tranexamic acid injection can be used as a hemostatic measure both intra- and postoperatively. When given preoperatively, a vial of tranexamic acid has been shown to significantly reduce the total blood loss during maxillary surgery.[61]

3.2 | Flap perforation

Adequate management of the primary flap in root coverage procedures is fundamental in order to achieve the expected results. Among the technical errors that can be committed during soft tissue manipulation, the most relevant mistake is flap perforation; that is, direct injury to the integrity and vascularization of the soft tissues resulting clinically in an "opening" within the flap extension. It is more likely to appear when performing the split-thickness incisions: during the "deep" split-thickness, if the blade is not maintained parallel and in contact with the bone while detaching muscular insertions from the periosteum; and also, at the time of "superficial" split-thickness, if the blade is not kept sufficiently parallel to the external flap surface while separating the muscle fibers from the inner aspect of the flap. In the latter surgical step, the presence of scars as a result of previous surgeries can cause mucosal adhesions that might further increase the risk of perforation. Flap perforation compromises its blood supply, leading to necrosis and affecting root coverage outcomes as well as the integration and survival of the underlying connective tissue graft, when applied (Figure 8). Therefore, this complication should be properly managed during the surgical phase. First, it is essential to overcome the perforation with a full-thickness approach using an elevator carefully and gently; then, it is possible to proceed with flap mobilization apical to the perforation in a split-thickness manner without increasing its dimensions. This reduces tension at the level of the perforation when the opening is small (ie, 1-2 mm) and located on top of a vascular bed (connective tissue or periosteum); no sutures are needed (Figure 9) unless continuous bleeding is still present at the end of the surgery, jeopardizing blood clot stability. If the perforation is greater than 2 mm or lies on an avascular area (root surfaces) (Figure 10), it is mandatory to close it using simple interrupted sutures with a thin thread and small needle (ie, 7.0 suture, 8 mm cutting needle, 3/8 circle) to avoid further damage to the soft tissues. Also, if the placement of a connective tissue graft was not initially considered, it is essential to include it whenever the perforation is located on the root surface in order to avoid undesirable results. Moreover, even though it has been shown that small (4 mm height) and thin (<1 mm) connective tissue grafts are effective for achieving complete root coverage,[62] in case of perforation the use of a connective tissue graft of larger size and greater thickness (at least 1 mm but <2 mm) is highly recommended (Figure 11). A closure of flap perforation should be accomplished at the end of the surgery in order to reduce tension at the level of the flap margin and the consequent risk of perforation opening.

3.3 | Nerve injuries

Owing to their anatomical location, there are two nerve structures of interest when treating gingival recessions: the infraorbital nerve and the mental nerve. The emergence of the infraorbital nerve is well beyond the area of deep dissection if the coronally advanced flap is performed adequately. Therefore, setting aside individual anatomical variations, injuries to the former are fairly rare in the context of mucogingival surgery.

However, during the treatment of the canine-premolar area in the mandibular arch, there is a latent risk of injuring the mental nerve. When dealing with deep gingival recessions in the aforementioned area, the operator should try to assess the location or proximity of the mental foramen with a periapical radiograph preoperatively. During the surgery, deep periosteal releasing incisions should be avoided; instead, the initial flap release can be performed by compressing the flap with a gauze in an apical direction (Figure 12A). With this technique, muscle fibers are released, allowing an easier distinction and separation between the deep plane (in which the fibers are inserted into the periosteum) and the superficial plane (characterized by the insertion of the fibers into the inner aspect of the flap) (Figure 12B,C). Afterward, superficial split-thickness dissection of the flap will ensure that the clinician does not encounter or sever main or accessory nerve fibers.

4 | POSTSURGICAL PHASE

Root coverage procedures are associated with patient morbidity, defined as a condition of being diseased[26] due to the risk of postoperative complications in the first 2 weeks after surgery, which represents a matter of concern for both clinicians and patients.[9] The most common early complications reported in the literature are pain, infection, swelling, bleeding, and hematoma formation.

Curtis et al,[63] in 1985, assessed pain and complications after different periodontal surgeries, including free gingival grafts and pedicle grafts. They showed that approximately 50% of the patients reported minimal or no postoperative pain, whereas 4.6% reported severe pain. Notably, 94.5% of the patients had no (46.1%) or minimal (48.4%)

FIGURE 8 A, Multiple gingival recessions affecting mandibular teeth. B, Modified envelope flap for multiple gingival recessions was performed with the addition of connective tissue grafts. C, Clinical photograph showing the postoperative situation immediately after suturing. Notice the presence of a perforation located apically to the cuspid. D, The perforation was closed with sutures using a small needle and thread. E, Situation 2 wk after the intervention showing flap fenestration and necrosis of the underlying graft, even though the perforation had been sutured. F, Close-up of the fenestration showing root exposure. G, Clinical situation after 3 mo revealing perfect root coverage and soft tissue integration except for the cuspid, in which the flap perforation led to failure of root coverage, determining a worse situation compared with the baseline

FIGURE 9 A, Envelope-type flap for multiple gingival recessions. The technique involves the tunnelization of the peripherical area through split-thickness incisions, which reduces the risk of perforation. Notice in the circled area the small perforation done with the tip of the blade. B, Clinical situation after 30 d showing excellent healing of tissues without any impact of the complication on the expected outcome.

postoperative complications, such as bleeding, infection, swelling, or adverse tissue changes. Moreover, mucogingival surgery was considered 3.5 times more painful than bone surgery. A positive correlation was found between duration and mucogingival surgery: the longer the surgery, the greater the reported pain. For the said study, it can be speculated that the increased pain after mucogingival surgery might be due to the harvesting procedures commonly adopted in the 1980s.

Later on, Griffin et al[64] evaluated the incidence of complications after free soft tissue grafting or subepithelial connective tissue grafting procedures at 1 week. They found that pain and swelling were the most significant complications, with 27%-40% of subjects reporting moderate or severe pain and 19%-60% of them reporting moderate to severe swelling.

A recent retrospective study[65] evaluated the incidence and severity of complications following oral, periodontal, and implant surgeries. A postoperative incidence ranging between 10% in the connective tissue graft procedures (usually only one complication in 9.7% of patients) and 19.7% using the free gingival graft

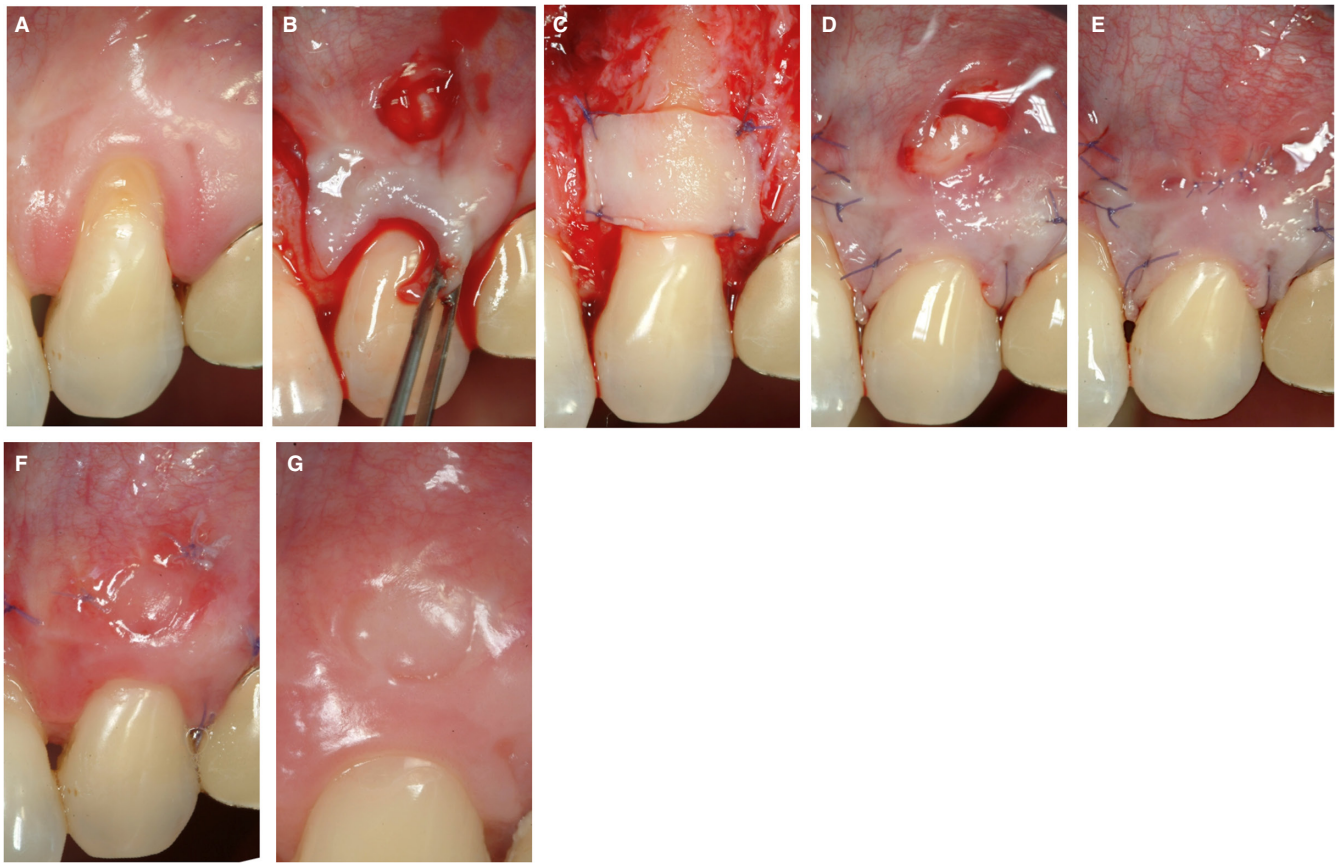


FIGURE 10 A, Deep gingival recession affecting left maxillary cuspid with an adequate amount of residual keratinized tissue and gingival thickness. The surgical plan included a triangular-shaped coronally advanced flap. B, A perforation was done in the middle part of the flap in correspondence to the root surface, forcing a change in the surgical plan. C, A connective tissue graft was added in conjunction with the coronally advanced flap in order to compensate for the occurrence of perforation. D, After the flap has been sutured, (E) the perforation borders should be closed as much as possible with a small needle and fine thread to reduce the opening of this area during the postoperative healing. F, After 2 wk, the clinical situation shows the loss of the sutures at the perforation with consequent exposure of the underlying connective tissue graft. G, After 3 mo, the clinical situation reveals a circular area of healing with a different appearance in terms of color and texture, which may represent an esthetic concern for the patient.

technique (usually only one complication in 19% of patients) was reported. Moreover, 2.3% of patients who underwent connective tissue graft procedures and 3.7% of those who underwent free gingival graft techniques experienced adverse effects on the surgery's success. Conversely, because of scarce evidence in terms of reported morbidity data,[66] the recent Cochrane review by Chambrone et al[8] did not provide values regarding the incidence of complications after root coverage procedures. They pointed out that discomfort was mainly related to donor sites of subepithelial connective tissue grafts and most of the times it was experienced within the first week after surgery with no influence on root coverage outcomes. Similar findings have been published recently in a network meta-analysis:[67] Connective tissue graft–based techniques have proven to increase patient morbidity compared with flap alone or the use of graft substitutes. Several complications, deriving from or unrelated to treatment errors, may be identified during the early and delayed postoperative stages after root coverage procedures (Figure 13)

4.1 | Early bleeding of primary site

A meager amount of bleeding might occur after root coverage procedures, especially if there are associated palatal harvesting techniques.[55] However, postoperative bleeding at the primary flap is an uncommon complication that may present merely as blood-tinged saliva, or it may become a hemorrhage that continuously fills the oral cavity with blood or even cause the formation of a "liver" clot, which can alarm the patient. Typically, the process of blood coagulation and fibrinolysis takes place after periodontal flap surgery. Immediately after vessel injury, platelets adhere to the subendothelial tissues at the injury site, aggregating to form the primary hemostatic plug. These platelets cause the activation of clotting factors, with the consequent formation of a fibrin clot that reinforces platelet aggregation.[68] Hence, platelets are key players in hemostasis. An insufficient number of platelets results in blood clotting disorders, leading to bloody discharge from periodontal wounds.

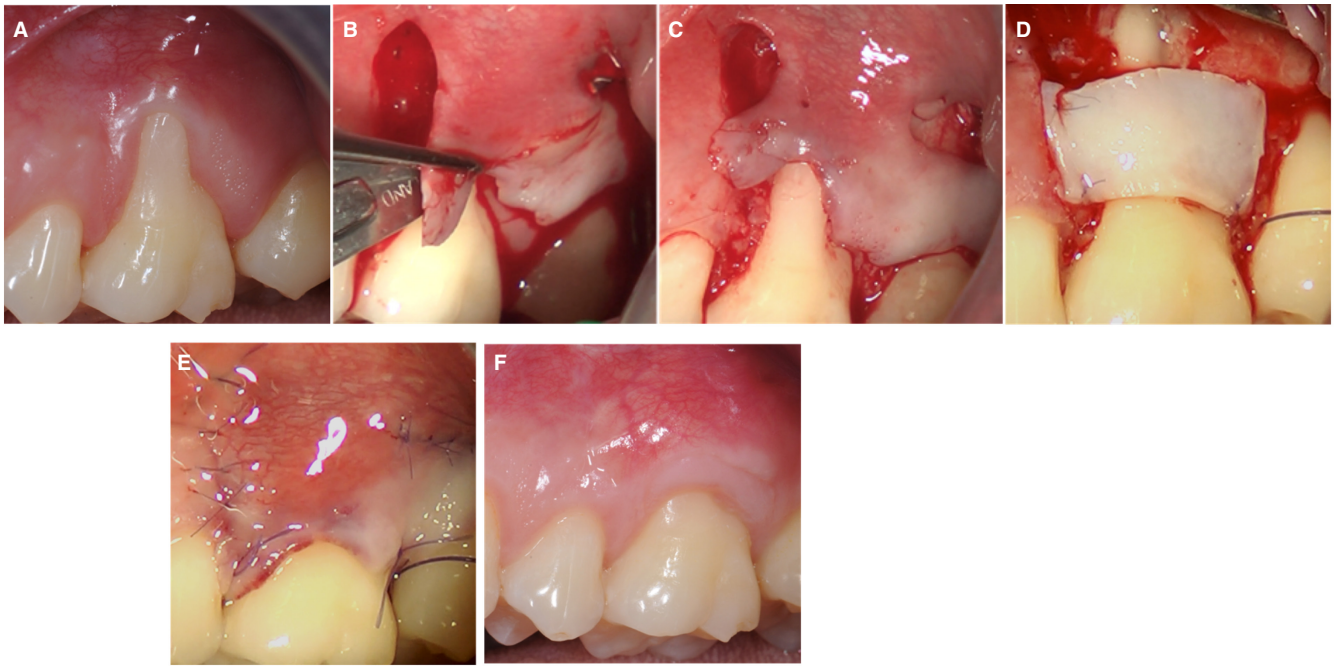
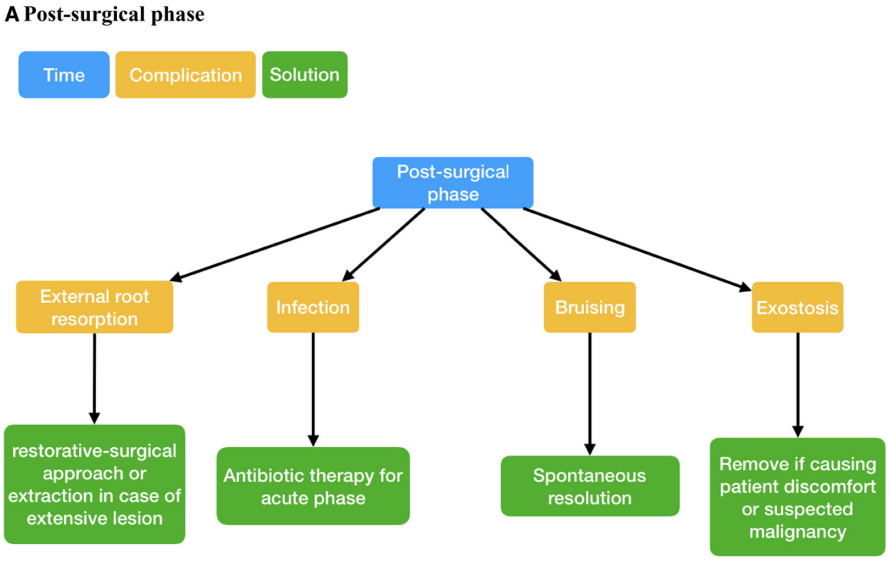


FIGURE 11 A, Deep gingival recession affecting the mesial root of this left maxillary first molar. This tooth represents a challenging area to be treated with root coverage procedures due to the presence of reduced visibility and strong muscular insertions from the cheek. B, A perforation occurred during the split-thickness performance, creating (C) a large opening in the covering flap. D, In this case, the use of a connective tissue graft had already been planned; however, the applied graft was larger and thicker than the standard dimensions adopted in the literature. E, Clinical situation immediately after the intervention: the coronal advancement of the flap was achieved, and the perforation was perfectly closed. F, After 6 mo of healing, the clinical situation shows satisfying results in terms of root coverage and soft-tissue appearance.

FIGURE 12 A-C, After full thickness flap elevation (A), the "gauze" technique (B) allows the release of muscle fibers, providing an easier distinction and separation between the deep plane (yellow arrow), in which the fibers are inserted into periosteum, and the superficial plane (green arrow) (C), characterized by the insertion of the fibers into the inner aspect of the flap

There are many causes for abnormal blood coagulation, such as liver disease, renal insufficiency, fibrinolysis, disseminated intravascular coagulopathy, leukemia, pharmaceutical agents, and genetic disorders that involve deficiencies of various clotting factors.[69,70] If the patient presents with significant postsurgical hemorrhagic sequelae, laboratory blood studies must be done to look into the possible causes.

"Liver clot" or "currant jelly clot" describes a red, jelly-like clot that is rich in hemoglobin from the erythrocytes within the clot; it usually results from venous hemorrhage, characterized by slow, oozing, dark blood hemorrhage.[71,72] According to the literature, the "liver clot" formation generally occurs 24-48 hours after surgical procedures[73–78] and it is usually located at the margin of the flap, extending up to the crowns of the involved and neighboring teeth (Figure 14). Secondary hemorrhage (occurring 24 hours after surgery) might be attributed to several factors: intrinsic trauma (ie, tongue, chewing, and intentionally pulling surrounding muscles), presence of foreign bodies, premature suture loss, or inadequate marginal stability of the flap (ie, due to errors during suturing technique and flap management) that may cause repeated, delayed organization of blood coagulum. Furthermore, it has been reported that vasoconstrictors included in the local anesthetic (ie, epinephrine) may produce rebound vasodilatation after the vasoconstriction effect has worn off, leading to increased risk for bleeding in the immediate postoperative period. There is a greater potential for such undesirable delayed hemorrhage following the use of 1:80 000 epinephrine than after the use of 1:100 000 epinephrine.[79] Following gentle removal of the "liver clot" with a sterile



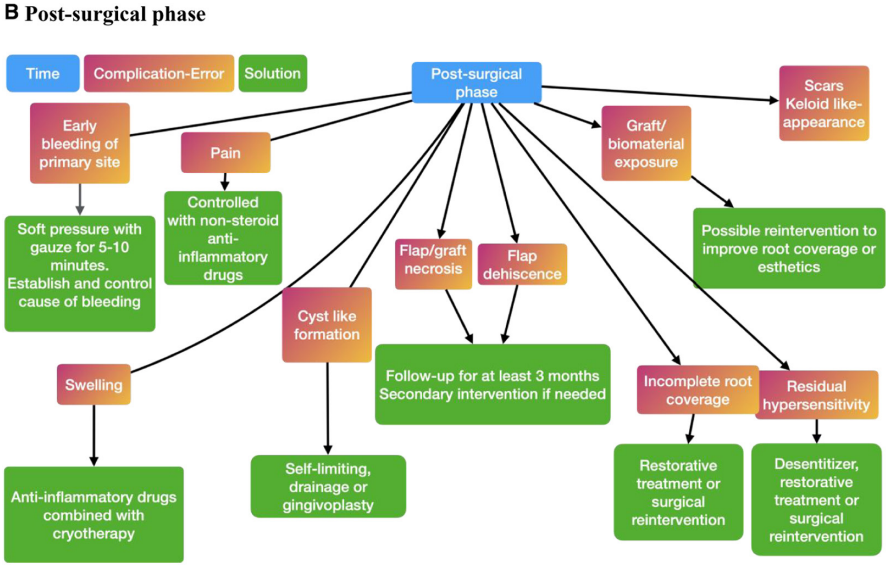


FIGURE 13 A, B Postsurgical phase

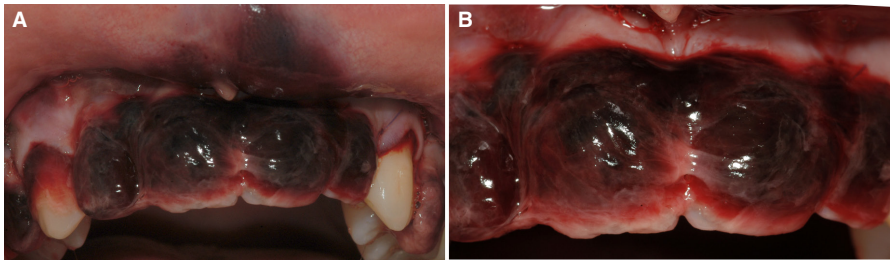


FIGURE 14 A, Clinical appearance of early bleeding at the level of the primary site called "currant jelly" or "liver" clot. B, Close-up A. The clot is rich in hemoglobin from erythrocytes and is usually located along the margins of the flap extending up to the crowns of interest and the neighboring teeth

gauze and saline irrigation, soft pressure is applied to the area of interest by interposing a gauze between the flap and lip/cheek, either dry or soaked with a hemostatic agent (ie, tranexamic acid), for about 5-10 minutes. The cause of bleeding should be established by interviewing the patient regarding traumatic episodes and evaluating the periodontal wound to assess if the sutures are in place. In the case of premature suture loss, new sutures should be placed to achieve flap stability in the marginal area, thus promoting blood clot stabilization. The patient should be discharged only once complete control of bleeding is achieved, and the importance of compliance regarding postoperative behaviors should again be stressed.

4.2 | Pain

Pain is defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage," which results in a highly subjective experience.[80]

Pain is a conscious experience: It is the interpretation of the nociceptive input influenced by memories, emotional, pathologic, genetic, and cognitive factors. Resultant pain is not necessarily related linearly to the nociceptive drive or input, and the behavioral response by a subject to a painful event is modified according to what is appropriate or possible in any particular situation.[81] Pain, by its various nature, is difficult to assess, investigate, manage, and treat. Some studies showed how a painful experience could occur without a primary nociceptive input,[82–85] further complicating the pain assessment, but perhaps providing an alternative explanation for how pain might arise in difficult clinical cases where the organic cause is not obvious.

Concerning surgical periodontal therapy, it has been suggested that pain perception by the patient is influenced by several factors associated with his or her emotions, such as anxiety, previous experiences, the anticipation of stress, and control of the environment.[86–92] Periodontal soft and hard tissue damage during surgical treatment and manipulation directly stimulates the nociceptor terminals in the peripheral tissue. It releases inflammatory cytokines and chemokines, which are the major causes of early discomfort and delayed wound healing after periodontal surgery.[93,94] Pain perception might be associated with surgical and surgeon-related factors, such as the complexity of the surgery, the experience of the surgeon, the duration of the surgery, the extension of the surgical site, the amount of anesthesia used, periosteal fenestration/ dissection, and the type of pain medication used following surgery.[63,64,93,95] Patients reported experiencing more pain, swelling, and bruising when the duration of the periodontal surgery was 60 minutes or longer.[96]

Pain perception is most commonly assessed using the visual analog scale, which has long been considered a valid, reproducible, and easy to use tool,[95] was introduced for mucogingival surgery in the 2000s.[97,98]

The visual analog scale consists of a 10 cm line delimited by two extremes of pain: "no pain" and "maximum pain." Patients are asked to mark along the line their perceived level of pain intensity, and the scale is scored by measuring the distance from the "no pain" end to the patient's mark. An additional indirect method proposed in the literature to evaluate postoperative pain is the number of analgesic pills taken by patients after root coverage surgery.[99–101] Despite the vast number of trials available in the literature dealing with gingival recession treatment, data regarding pain is heterogeneous, and several systematic reviews[5,6,8,67,102] failed to produce a meta-analysis. In root coverage procedures, a substantial amount of patient morbidity is attributed to postoperative pain related to soft tissue harvesting from the palate.[5,6,8,67,102] However, multicenter randomized clinical trials have recently shown that the recipient site might also be a significant contributor for pain assessment during early healing, according to patient-reported outcomes evaluated through visual analog scale and oral health impact profile questionnaire (measuring the influence of the surgical intervention on a patient's life).[103] Trials focusing on the healing of palatal donor sites have concluded that the mesiodistal size of the graft does not seem to be associated with postoperative pain, but that characteristics like the apicocoronal dimensions and thickness of the graft may have more influence on perceived pain.[62,104] The proper understanding of pain intensity and variables that affect soreness is essential because pain may produce emotional responses that could affect compliance.[87] By providing adequate information about the level of pain after various surgeries and the associated factors influencing pain, clinicians will help patients have realistic expectations of their surgical procedures, enhancing the dentist-patient rapport.[105]

Pain management after root coverage procedures is reasonably straightforward: It is usually achieved with nonsteroidal anti-inflammatory drugs (ie, ibuprofen) immediately after the surgery and recommended in the following days according to the patient's needs.

4.3 | Swelling

Swelling is part of the body's repair process and is considered a normal reaction to surgery. Intra-oral surgical trauma always determines injury characterized by hyperemia, vasodilatation, and increased capillary permeability with liquid accumulation in the interstitial space. Edema is the expression of exudates or transudation, and it is likely that both events occur in surgery. Swelling becomes apparent after the day following surgery and will reach its peak within 2-3 days postoperatively, typically subsiding within 4-5 days[106,107] (Figure 15). In a practice-based evaluation of 500 patients consecutively treated with subepithelial connective tissue grafts, swelling incidence was very low (5.4%). None of the potential predictive factors included in the analysis (ie, age, sex, smoking, the purpose of the

FIGURE 15 Swelling appearance 2 d after surgery for treatment of multiple gingival recessions localized at the left side of the maxillary arch.

graft, recipient site size, or defect location) were directly associated with this complication.[108] On the other hand, the prospective study by Griffin et al[64] reported a higher incidence of moderate and severe swelling when bilaminar procedures are performed in comparison with free soft tissue grafting techniques (31.6% vs 21.3%). They found that swelling occurrence was more likely in smokers (three times) than in nonsmokers, especially when bilaminar procedures with autogenous grafts were adopted. Furthermore, lengthy procedures were more likely to result in moderate or severe swelling when autogenous tissue was used.[64]

Cryotherapy (ie, ice packing) is largely applied empirically to manage postoperative swelling and discomfort. However, to our knowledge, no specific data for root coverage procedures have been reported in the literature. In a literature review by Greenstein,[109] where seven studies were analyzed, only two trials showed that locally applied cold therapy after third-molar extractions might reduce postoperative swelling and pain, confirming the inconclusive data and advocating more clinical trials to assess the additional benefit of cold therapy. The time interval for cold applications varied in different studies, but there seemed to be a consensus among clinicians that cryotherapy should be applied for 10-20 minutes followed by a rest period. The total duration of therapy ranged from 2 to 48 hours. In a recent meta-analysis, Marques do Nascimento-Júnior et al[110] highlighted the lack of standardization of cold application or effective evidence-based treatment protocols for cryotherapy after third-molar surgery, concluding that cryotherapy may have a small benefit in reducing pain after third-molar surgery, but it is not effective on facial swelling and trismus.

In light of the foregoing, the intake of pain killers with an anti-inflammatory effect combined with cryotherapy in the immediate postsurgical phase might help to control swelling and pain.

4.4 | Bruising

A bruise is defined as "an injury involving rupture of small blood vessels and discoloration without a break in the overlying skin."[111] It is not an uncommon postoperative sequela after root coverage procedures, and it might appear at the level of the flap's external mucosa (Figure 16A) or even involve facial skin, in which case it represents an esthetic concern for the patient (Figure 16B). However, to the best of our knowledge, no evidence has been reported correlating the influence of bruise formation on wound healing. Therefore, no medical therapy is generally required, as a complete and spontaneous resolution occurs in a few weeks.

4.5 | Flap dehiscence

The first 14 days after root coverage procedures are considered of paramount importance in terms of flap stability for successful wound healing.[112] In this period, traumatic or inflammatory/infective injuries may represent a cause for its dislodgement.[113,114] Early flap dehiscence—defined as a condition in which two layers, previously stitched together, separate or rupture[71]—may appear as a complication during this time frame. This event usually leads to flap shrinkage, with severe consequences for the expected results in terms of root coverage. In order to understand how to deal with such undesirable outcomes, it is mandatory to know the potential factors correlated with flap dehiscence.

The first key factor to take into consideration for avoiding or reducing the risk of flap dehiscence is the adequate management of flap tension. One of the main features of performing the coronally advanced flap is eliminating muscle tension on the flap and its passive displacement in the coronal position.[59] The final passive position of the flap can be achieved through adequate split-thickness (deep and superficial) flap management as previously reported and described by de Sanctis and Zucchelli.[59,115,116]

A split-mouth randomized trial for the treatment of single gingival recessions[117] reported that minimal residual flap tension (0.4 g) does not affect the final outcome of coronally advanced flap procedures; however, increasing flap tension (6.5 g) was associated with reduced root coverage percentages. Similar findings have been reported by Burkhardt and Lang,[118] who revealed that primary wound closure after 1 week of healing was achieved in 100% of the implant sites when flap tension was minimal (0.05 N); if more tension was applied to the wound margins, but still in a low range of 0.05-0.10 N, a small proportion (10%) exhibited

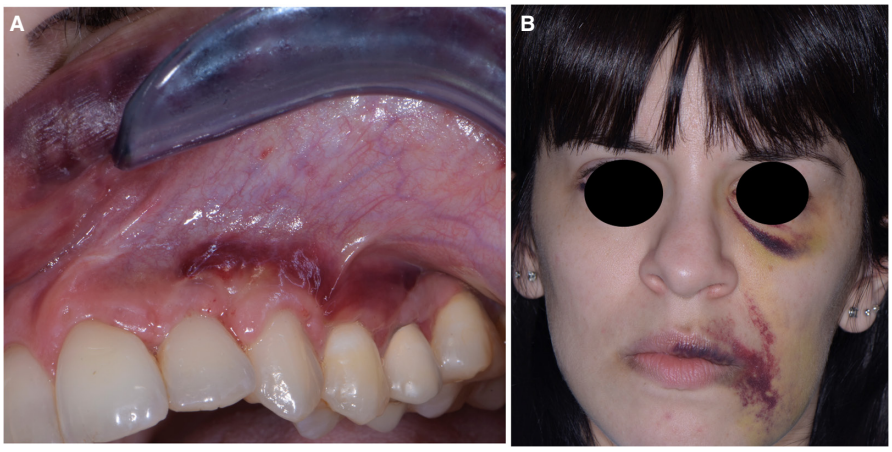


FIGURE 16 A, Bruising appearance localized at the level of the flap's external mucosa after a root coverage procedure. B, This can involve the facial skin, representing an esthetic concern for the patient.

wound dehiscence. When exceeding the 0.10 N tension limit, the incidence of dehiscences increased dramatically to 40%-100%.[118] Flap passivity is pivotal for coronally advanced flap procedures, because placing tight sutures in order to overcome residual flap tension may cause strain on the vascular system, reducing vessel patency and impairing neovascularization.[119] An angiographic study on humans supports the hypothesis that the best clinical outcomes, in terms of root coverage, are achievable when the flap is passively adapted and sutured without tension over the exposed root surface.[120] If the flap is not completely released, residual tension could favor a postoperative apical shift of the gingival margin during the early phase of healing.[119]

The second crucial aspect for reducing/avoiding the risk of flap dehiscence when performing a coronally advanced flap is the appropriate de-epithelialization of the anatomical papillae, removing all the epithelium and leaving as much connective tissue as possible. This is one of the most important surgical steps, given that the de-epithelialized anatomical papillae represent the most coronal connective tissue bed for the anchorage of the surgical papillae, thus ensuring vascular exchange, the survival of the marginal aspect of the flap, and improving blending (in terms of color and thickness) of the surgically treated area with respect to adjacent soft tissues.[59]

In order to reduce the risk of losing anatomical papilla height, de-epithelialization is undertaken in two steps using two different instruments. The first step is done with the insertion of the blade tip into the connective tissue layer exposed by the incision/elevation of the split-thickness surgical papillae, keeping it parallel to the external gingival surface. The process is continued with microsurgical scissors, because they are the only ones capable of handling the tip of the papillae effectively. Microsurgical scissors can de-epithelialize even particularly narrow papillae, providing greater accuracy in the removal of the whole epithelial layer.[121] If some epithelium were to be left at the level of the anatomical papillae, it might interfere with the vascular exchange and determine premature flap dehiscence with a detrimental effect on the expected outcome.

The last, but not the least, crucial aspect for reducing/avoiding the risk of flap dehiscence is optimal surgical stability, meaning wound stability through an effective suturing technique. Regarding the coronally advanced flap, the main stabilizing sutures are the final sling sutures suspended around palatal/lingual cingula that fix the surgical papillae on top of the interdental connective tissue beds and provide for a precise adaptation of the flap margins over the underlying convexity of the crowns.[59] Sling sutures, also called suspended sutures, are the most precise way to position a flap coronally because the flap is attached to a fixed anchor point (teeth) rather than another movable flap.[122,123] A recent cadaver study[124] tried to compare the influence of different suturing techniques (interrupted sutures, sling sutures, and sling and tag sutures) on the performance of coronally advanced flaps, finding greater marginal flap stability using sling and tag and sling sutures rather than interrupted sutures alone. This tight marginal adaptation is essential for promoting wound healing and blood clot stabilization,[112,114] underlining the importance of not having any blood seeping from the sulcus at the end of surgery. In the vertical releasing incisions, single interrupted sutures are performed to achieve primary intention wound healing.[59]

Together with suturing techniques, the selection of microsurgical sutures has been shown to reduce the risk of tissue trauma. In fact, choosing finer suture diameters (6-0, 7-0 sutures) leads, in case of excessive tension, to thread breakage rather than tissue damage.[125,126] Furthermore, it has been established in an angiographic study[127] that minimally invasive (microsurgical) techniques can lead to less tissue trauma, since sharper and finer surgical blades, together with smaller suture material and magnification, might be responsible for reduced tissue impairment, decreasing vessel injury in the first 7 days; the less the trauma, the lower the chances of ending up with flap dehiscence. This microsurgical approach seemed to affect root coverage outcomes as well; in fact, gingival recessions treated with minimally invasive procedures reported better root coverage percentages at short- and long-term follow-ups.[127]

Occasionally, even if the flap has been adequately prepared (free from tension and competently sutured), flap dehiscence due to premature suture loss can still occur if there is excessive swelling or if the area is accidentally traumatized in the days immediately following the surgery.

Particular care should be taken in the mandibular anterior area. As a matter of fact, gingival recessions affecting the anterior mandibular zone are very challenging due to the peculiar anatomical conditions, such as shallow vestibule, thin gingival tissues, frenum pull, and minimal keratinized tissue, all of which contribute to the lower percentages of root coverage reported in the literature for said area.[128,129] A randomized clinical trial has recently introduced a surgical modification of the coronally advanced flap that includes removal of the submucosal tissue[130] to reduce/delay early muscle reinsertion on the flap. In that study, better root coverage outcomes and lower flap shrinkage were reported for sites treated with this novel procedure.

In case of early flap dehiscence, no intervention is recommended; clinicians should wait for soft tissue healing and stabilization (at least 3-6 months) and then reevaluate the clinical results. Sometimes, the occurrence of flap dehiscence does not necessarily turn into a complete failure, especially when the procedure involves the adjunction of a connective tissue graft. In fact, in such cases, soft tissue healing and maturation may determine the achievement of the expected outcomes (Figure 17). However, whenever the anticipated results have not been achieved or do not satisfy patient expectations, a second surgical step might be necessary to solve the recurrence of the gingival recession (Figure 18).

4.6 | Graft/biomaterial exposure

Root coverage procedures are performed mainly for esthetic reasons,[2] with the ultimate goal of obtaining perfect soft tissue integration among the treated area and the adjacent teeth. With this in mind, the root coverage esthetic score[3,131] was proposed in 2009 in order to record (from 0 to 10 points) the final esthetic outcome

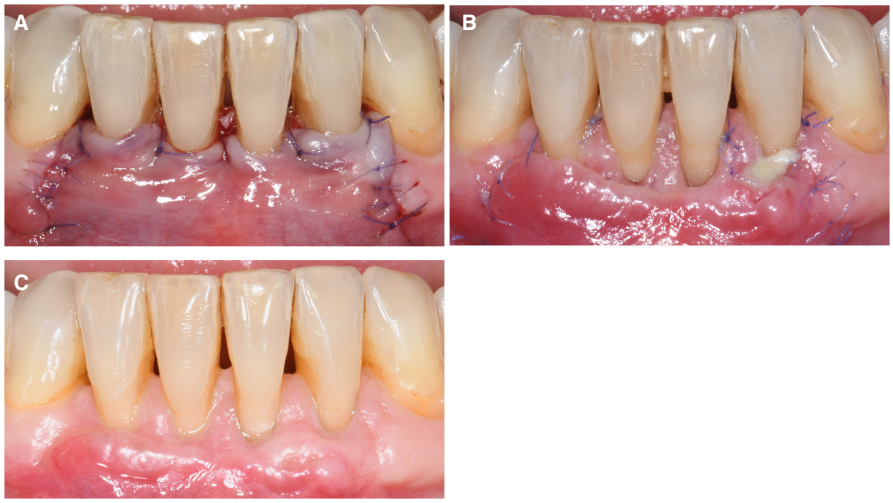


FIGURE 17 A, Clinical photograph showing the postoperative situation immediately after a root coverage procedure with a coronally advanced flap plus connective tissue graft. B, Situation 2 weeks after the intervention showing flap dehiscence. C, Clinical view at 1 mo revealing soft tissue improvement. In this situation, clinicians should wait at least 3 mo before planning further surgeries in the case of an unsatisfied patient

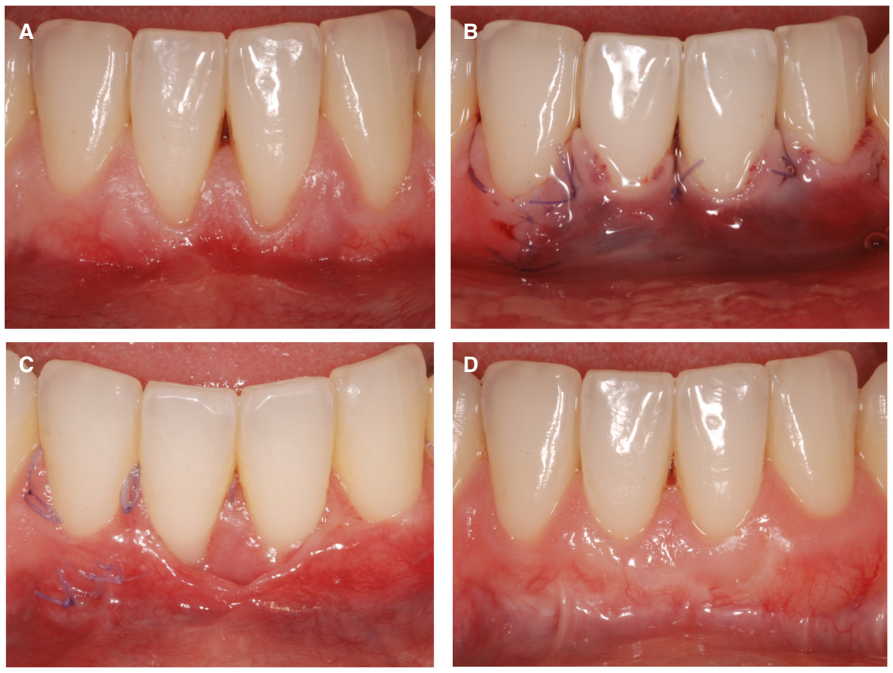


FIGURE 18 A, Preoperative facial view of mandibular incisors affected by gingival recessions treated with a coronally advanced flap plus connective tissue graft. B, Immediate postoperative view. C, Clinical situation at the time of suture removal (2 wk) showing flap dehiscence with the consequent exposure of the root surface of the two central incisors. D, Although flap dehiscence occurred, soft tissue integration and complete root coverage were achieved after 3 mo.

of root coverage procedures from a professional standpoint. This score considers the amount of root coverage achieved (6 out of the 10 points) and other aspects correlated with soft-tissue appearance. However, Kim et al[132] have shown that the patient's perception of esthetics was not always consistent with professional scoring, since patients are more attentive to soft tissue appearance (color and texture) than the amount of root coverage.

In light of the foregoing, in order to achieve "overall success" in these kinds of surgical procedures, it is safe to say that the same level of importance should be given to both root coverage percentage and soft tissue integration.[66] The combination of a coronally advanced flap and a connective tissue graft is considered the gold standard for achieving the best root coverage. However, one of the main complications with this technique is graft exposure during the postoperative period. This might occur prematurely (within the first 1-2 months after the surgery) or be delayed. Undesirable sequelae for this event include an unpleasant appearance due to lighter tissue color and/or a different texture in comparison to neighboring soft tissues (Figure 19).

In order to avoid or minimize premature graft exposure, some fundamental surgical steps have to be respected. Regarding the position of the graft, it should be secured at the level of the cemento–enamel junction or slightly apical to it,[133] but never coronally. In terms of thickness and size, it has been shown that using "small" grafts allows for better esthetic outcomes and minimizes impingement on the flow of blood supply from the underlying connective tissue bed to the coronally advanced covering flap.[62,133] Consequently, less early flap shrinkage has been reported by reducing the graft dimensions. Another aspect is flap suture: Flap margins should be positioned 1-2 mm coronal to the cemento–enamel junction[134] to obtain greater root coverage percentages and to avoid graft exposure by compensating for the physiologic postoperative flap shrinkage. It

should also be noted that graft exposure and early flap dehiscence are strictly correlated, and all the recommendations expressed in the corresponding section should be kept in mind.

Concerning delayed graft exposure, it might be possible to observe it after 9-12 months from the surgery. It is possible to speculate that, despite a well-performed surgery and excellent healing, the quality of the connective tissue harvested from the palate may determine a continued maturation of the graft under the flap, eventually leading to its exposure (Figure 20). The occurrence of this complication is a relevant event for patients with high esthetic demands due to the altered appearance of the treated soft tissues (ie, different color and/or texture).

FIGURE 19 Connective tissue graft exposure 3 months after surgery, resulting in an unesthetic and unpleasant appearance from both the patient's and clinician's standpoint

In the aforementioned scenarios, surgical reinterventions (such as gingivoplasty, removal of the exposed part, and performance of a second root coverage surgery) are the only viable options to solve the patient's esthetic concerns (Figure 21). The gingivoplasty, which reduces the volume and may improve tissue texture, does not represent a definitive solution because the soft tissue white appearance would remain. In the end, if the patient does not accept the final esthetic outcome, a second root coverage procedure should be performed, including complete removal of the connective tissue graft exposure.

Recently, porcine-derived matrices have been introduced as connective tissue substitutes in root coverage procedures, with the ultimate goal to reduce postoperative morbidity by avoiding a second surgical site. They are becoming quite popular among clinicians and patients, with encouraging results so far.[135–138] Most of these new biomaterials have been designed to be entirely covered by a tension-free primary flap (submerged healing)[138] and, because of their expected resorption, they are usually used in bigger sizes compared to those of the connective tissue graft. However, in the case of matrix exposure during the postoperative period, contrary to the connective tissue graft, it tends to resorb. Generally, there are no consequences when the exposure involves the vertical releasing incisions (Figure 22) but it can lead to partial root coverage in case of coronal exposure of the matrix. Therefore, patient complaints regarding color or texture will not be an issue, but the recurrence of gingival recession can result in an unsatisfied patient, in which case a second surgery should be performed to improve the outcome.

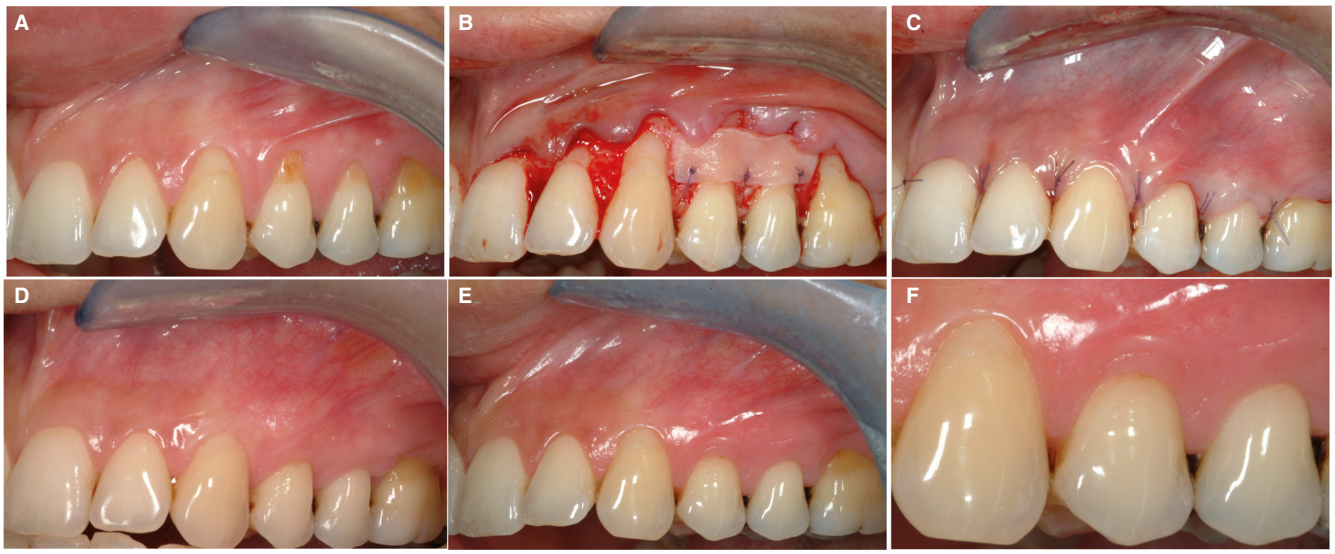


FIGURE 20 A, Multiple gingival recessions affecting left maxillary quadrant. B, C, Treatment with an envelope-type coronally advanced flap in combination with site-specific adjunction of connective tissue grafts. D, Follow-up at 6 months reveals a successful root coverage and optimal soft tissue blending. E, At the 12-month visit, however, the graft at the level of the first premolar became exposed, resulting in a double marginal contour. F, Close-up of the exposed grafted tissue

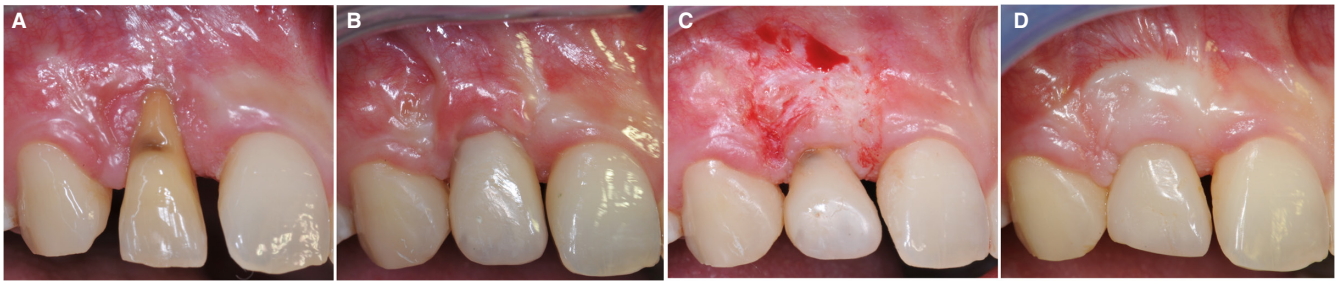


FIGURE 21 A, Clinical presentation of a gingival recession defect on the maxillary right lateral incisor associated with radicular caries. B, Clinical appearance 3 mo after the performance of coronally advanced flap plus connective tissue graft and provisional veneer delivery. Notice the connective tissue graft exposure responsible for inadequate soft tissue integration with the adjacent tissues. C, Gingivoplasty was performed using a bur to improve soft tissue texture and volume. D, Final situation after delivery of final veneer, showing an area of lighter color than the adjacent tissues

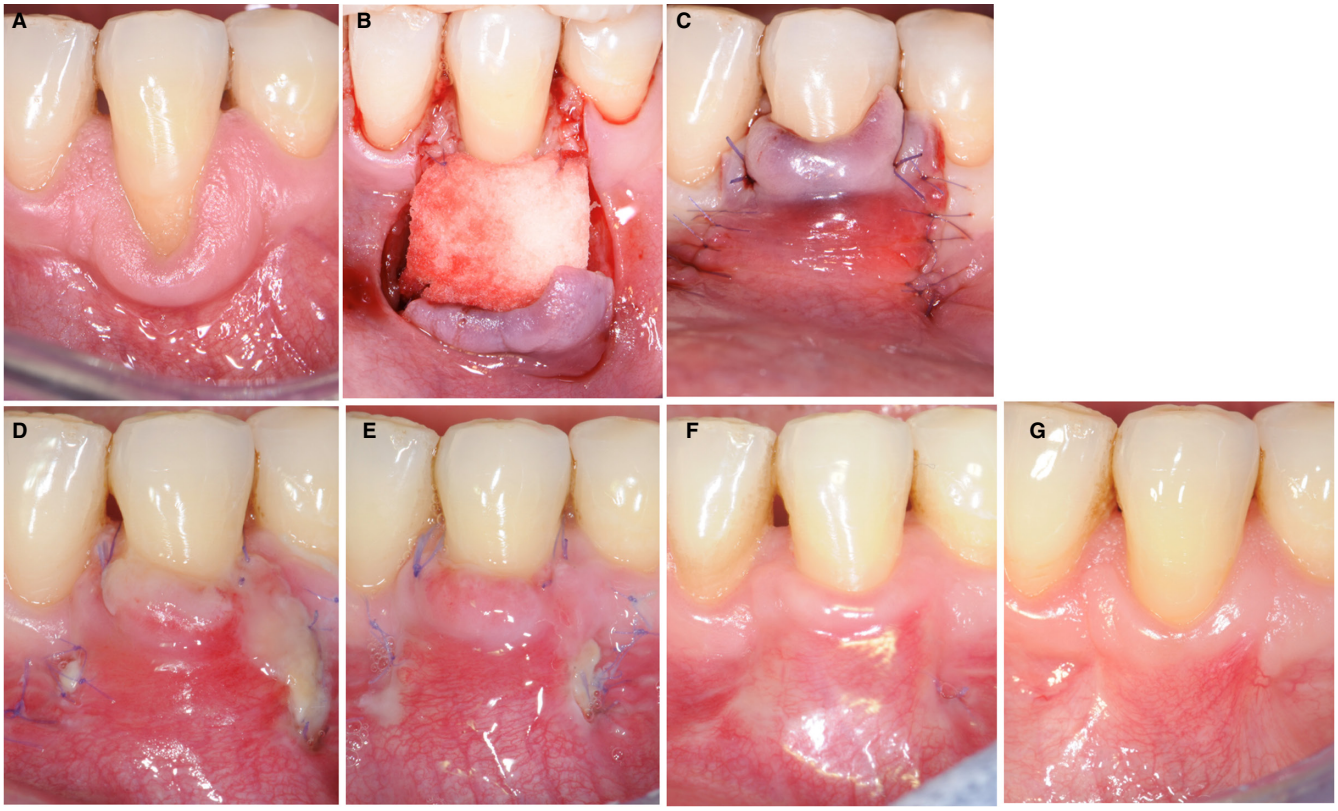


FIGURE 22 A-C, Treatment of a mandibular gingival recession with the coronally advanced flap for single defects combined with the use of collagen matrix. D, At 1 wk after the surgery, wound dehiscence along the vertical releasing incisions occurred with the consequent exposure of the underlying collagen matrix. E, At 2 wk after the surgery, the clinical situation shows wound dehiscence improvement; F, its complete resolution at 30 days. G, The follow-up at 6 months reveals a successful outcome regarding root coverage and soft tissue integration. Reproduced with permission from Springer Nature *Clin Oral Investig* 2020:24: 3181-3191

4.7 | Scars/keloid-like formations

Scars and keloid-like formations resulting from root coverage procedures may become esthetic concerns. They can happen along the flap incisions or around suture sites, determining a localized formation with a texture and color that differs from the adjacent soft tissues. Depending on the treated area, these alterations could become visible during smiling, affecting the treatment outcome and compromising esthetics (Figure 23).

Scar tissue is characterized by excessive accumulation of disorderly arranged collagen (mostly type I and III), proteoglycans, and persistent myofibroblasts, which leads to aberrant function of the tissues.[139] Compared with the healing of skin wounds, the oral mucosa is less prone to scar formation owing to its different inflammatory cell infiltrate with lower levels of macrophages, neutrophils, and T-cell infiltration and a lower level of the pro-fibrotic cytokine transforming growth factor beta 1.[140–142] Clinical observations suggest that surgical wounds, especially in the oral keratinized

attached gingiva and palatal mucosa, heal with minimal scar formation.[143] According to our clinical experience, incisions or sutures performed in alveolar mucosa can lead to scar formation. Sutures anchored to the underlying periosteum, if performed at the level of the alveolar mucosa, may lead to the formation of white and flat scars. It has also been reported that increasing closing tension may lead to higher tensile strength on the tissues and, consequently, to a stronger scar with increased collagen deposition.[104] In root coverage procedures including vertical releasing incisions, these should be done as short as possible, avoiding placing them on buccal root prominences and beveled so that the bone and periosteal tissues are not included in the superficial cut and thus do not participate in the healing process. By doing so, techniques requiring vertical releasing incisions are less prone to result in unesthetic scar formation[144] (Figure 23).

Whereas small, shallow wounds may result in flat scars, as previously mentioned, more extensive, deep wounds can lead to atrophic, hypertrophic, or keloid scars.[143] The latter are defined as a growth of extra scar tissue that usually occurs where the skin has healed after an injury.[145] Whereas keloid denotes skin lesions, the hyperplastic response is the designation for oral mucosa.[146] In root coverage procedures, it may be possible to observe keloid-like formation due to soft tissue hyperplastic response along vertical releasing incisions or periosteal incisions at the level of alveolar mucosa (ie, recipient bed for free gingival graft). Their characteristics include a difference in volume, color, and texture compared with the adjacent areas that may have a negative impact on the patient's esthetic satisfaction.

Overall, scars in the alveolar mucosa are seldom noticed by patients or are considered acceptable, as they are located apically to the "pink" area exposed during a smile. However, the occurrence of keloid-like formations deserves separate mention because it represents a challenging clinical situation to deal with from a surgical and psychologic standpoint.

4.8 | Flap/graft necrosis

One of the most important aspects of the success of root coverage procedures is that, from a biological point of view, healing depends on the interface between a flap or connective tissue/free gingival graft and a denuded avascular root surface. The survival of the soft tissues positioned above the root, regardless of the technique employed, is strictly correlated to two factors:

- First, the recipient bed (consisting of bone covered by connective tissue/periosteum) should, in the areas surrounding the recession defect, be wide enough to allow the invasion by cells and blood vessels of the recipient bed as well as of the tissue graft of the fibrin layer from which it is gradually replaced by connective tissue. In the case of a free soft tissue graft placed over a denuded root surface, healing depends on diffusion of plasma and subsequent revascularization from those parts of the graft resting on the connective tissue bed surrounding the dehiscence.[147,148] The establishment of collateral circulation from adjacent vascular borders of the bed allows the healing phenomenon of "bridging."[149] Hence, the amount of tissue that can be maintained over the root surface is limited by the size of the avascular area,[147,149] and the survival of the graft is strictly correlated to its thickness.[150]
- Second, the pedicle flap, when used by itself for root coverage purposes, has to ensure its survival above the avascular root surface, and it can also represent the second source of vascularization for the underlying connective tissue graft when bilaminar techniques are adopted. The healing in the area where the pedicle flap is in contact with the denuded root surface follows the four-stage healing process introduced by Wilderman and Wentz.[151]

When a small amount of blood flows to the tissue, necrosis may occur. This is defined as the death of body tissue that can derive from injury, radiation, or chemicals, and it cannot be reversed.[152] In root coverage procedures, tissue necrosis may involve the pedicle flap, the connective tissue graft in bilaminar techniques, and the free gingival graft. An inadequate flap design (reduced base of the pedicle flap) and/or thickness (too thin) may determine vascular distress and a consequent tissue necrosis.

In the case of the bilaminar technique, early flap dehiscence, by partial or complete necrosis of the flap, may affect the premature connective tissue graft exposure and its necrosis might occur (Figure 24).

When the free gingival graft is used for the purpose of root coverage, the necrosis usually regards the central part above the avascular root surface, especially if the recipient bed, graft size (dimension and thickness), and graft stabilization are inadequate (Figure 25).

In order to avoid the occurrence of soft tissue necrosis, it is crucial to respect the previously mentioned rules regarding flap/graft management. It is of paramount importance that adequate pedicle flap design considers specific characteristics—such as surgical papillae with appropriate dimension and thickness, vertical releasing incisions parallel or slightly divergent, and proper flap thickness—to reach an overall suitable flap vascularization. Moreover, it seems that adrenergic vasoconstrictors included in the anesthetics may result in ischemic necrosis of surgical flaps (mainly if norepinephrine is used instead of epinephrine) due to local ischemia with subsequent tissue acidosis and accumulation of inflammatory mediators. Consequently, in root coverage procedures, the technique of local anesthetics injections is also a matter of concern. It is advisable to start the injection from the periphery of the flap at the mucogingival fold level to avoid soft tissue trauma due to needle penetration and to reduce the local ischemia due to the presence of a vasoconstrictor. In this manner, the anesthetic solution can reach the surgical area thanks to the diffusion mechanism.

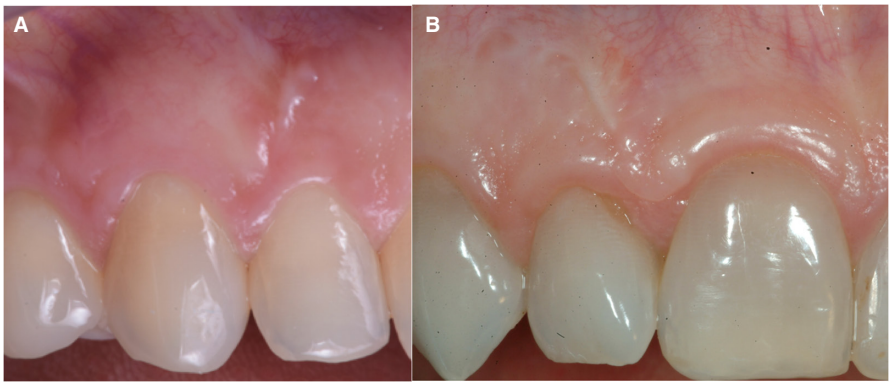


FIGURE 23 Facial view of, A, a right maxillary cuspid and, B, central incisor treated with a coronally advanced flap with vertical releasing incisions at which scars/keloid-like formations are noticeable.

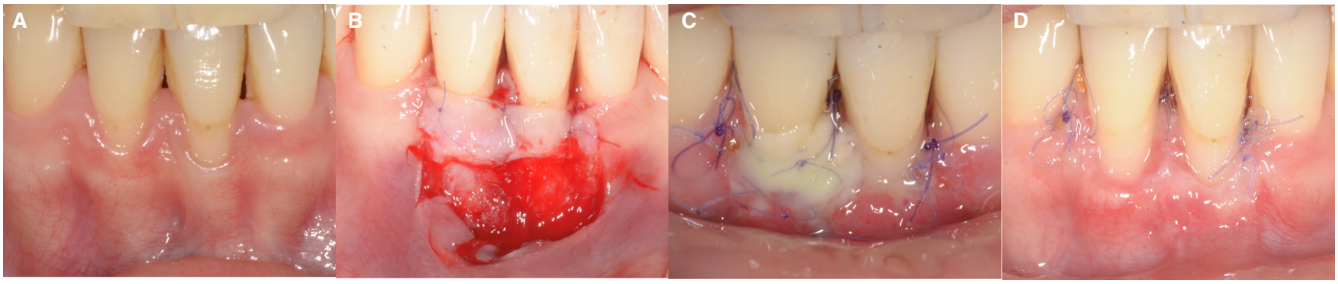


FIGURE 24 A, Clinical appearance of gingival recessions at central mandibular incisors; B, treatment with coronally advanced flap in conjunction with a connective tissue graft. C, At 1 wk after the surgery, the patient presented with flap necrosis. D, This ended up at 2 weeks with deeper gingival recessions compared with baseline

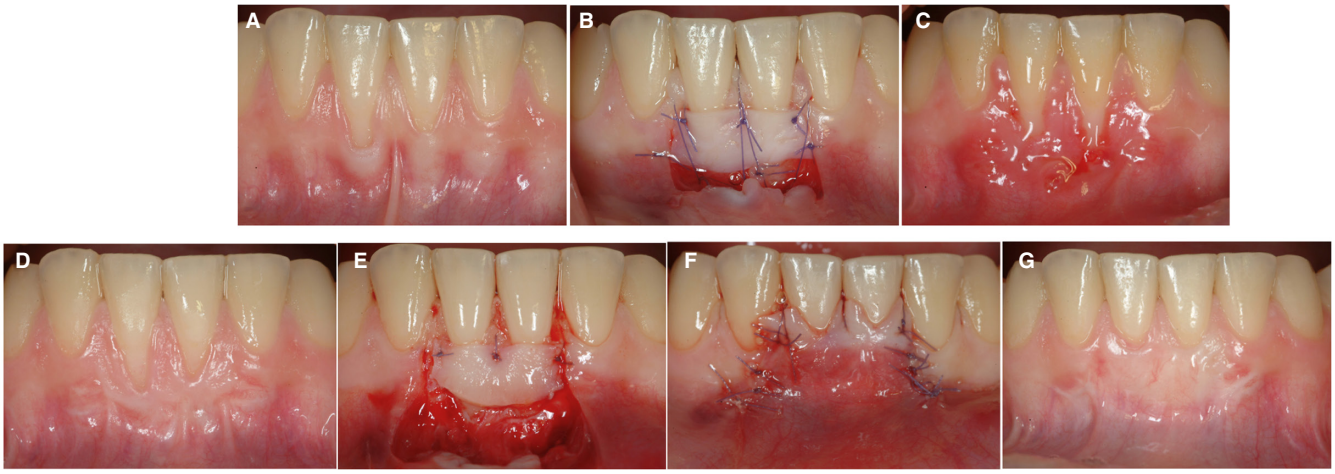


FIGURE 25 A, Gingival recession affecting a central mandibular incisor. B, Free gingival graft procedure was adopted to solve the root exposure and also to increase keratinized tissue at the level of the adjacent tooth. C, Clinical appearance after 14 days revealing the failure of the treatment determining even worse gingival conditions. D-F, After 3 months of healing (D), a new surgery (E, F) was performed to fix the previous situation using a coronally advanced flap plus connective tissue graft. G, The second surgery was uneventful, with a successful outcome in terms of root coverage

Whenever soft tissue necrosis occurs, we suggest checking this complication by following up the healing for at least 3-6 months and reevaluating the clinical situation for a second corrective surgery. If necrosis is associated with swelling, pain, local lymphadenopathy, and pus emergence from the sulcus at the time of the occurrence, antibiotic prescription is recommended.

4.9 | Infection

Like any other periodontal procedure, the root coverage procedure is performed in a contaminated setting: the oral cavity. Therefore, it follows that wound infection could occur due to the oral environment per se or in conjunction with flap fixation and suturing techniques.[142]

Using a strict aseptic technique, syringe irrigation to remove bacteria during wound cleansing, removing possible foreign bodies, and careful debridement of all teeth are prerequisites for proper surgical interventions.[142,152] Performing rinses with 0.2% chlorhexidine digluconate solution for 1 minute immediately prior to periodontal surgery has been recommended to reduce bacterial load in the oral cavity.[153–155] It has also been reported that the use of chlorhexidine following periodontal surgery can significantly contribute to the reduction of the infective burden in the oral cavity, and hence the promotion of oral health postsurgically.[142,156–159] As there is a delicate balance between the host's resistance to infection and factors initiating or promoting infection, on rare occasions infections might still appear after gingival recession treatment, despite all the efforts mentioned herein. Given that soft tissues are highly capable of resisting and fighting infections, only antibiotic therapy is recommended to deal with the acute phase.

4.10 | External root resorption

External root resorption is a progressive and destructive loss of tooth structure that manifests itself in a mineralized or denuded area of the root surface.[160] According to Heithersay,[161] periodontal surgeries that might potentially damage root cementum can result in resorption in 1.6% of cases. This is a rare occurrence following mucogingival surgery, with just a few studies (only case reports) available in the literature documenting this complication.[162–164] External root resorption, also called invasive cervical resorption when located in the cervical area of the tooth,[161] is one of the least known and understood forms of external root resorption; it is uncommon, insidious, and often aggressive, and it has been reported after the treatment of gingival recessions with connective tissue grafts. According to the extension and amount of tooth impairment, different treatment approaches have been adopted in the previously mentioned studies: from extraction up to restorative-surgical approaches to save the tooth. Undoubtedly, the treatment of invasive cervical lesions is more predictable when an early diagnosis is made. Hence, it is of utmost importance to also put patients who have undergone root coverage procedures under periodic maintenance care in order to detect any modifications at the subgingival level in a timely manner (Figure 26).

We suggest a restorative-mucogingival approach[165] to treat this complication. First, a clinical evaluation and intraoral X-ray must be done to understand the extension of the lesion and to decide whether or not to intervene. It is also crucial to check tooth vitality to exclude endodontic involvement. Usually, invasive cervical resorption appears as an irregularly shaped lesion localized in the midfacial portion of the root. Flap elevation is recommended for adequate visualization of the entire lesion so that it can be properly cleaned from granulation tissue and bone ingrowths. Afterwards, the field should be isolated using the rubber dam, and then the cavity is recontoured using burs and filled with a flowable composite. In the literature, other restorative materials have been suggested to fill the lesions, like glass-ionomer cement, composite resin, calcium silicate–based cement, and calcium-enriched mixture cement.[165] There is not enough evidence regarding the superiority of one material over another; in any case, the restoration must be as smooth as possible to allow the reattachment of connective fibers of the flap's inner aspect above the root surface. Once the cavity has been restored, the mucoperiosteal flap is replaced and secured in position[166] (Figure 27). Even though further investigations are needed, this restorative-mucogingival approach has been shown to be predictable, assuring long-term outcomes (up to 5 years) (Figure 28).

4.11 | Exostosis

Exostosis is reported as a peripheral localized benign bone overgrowth of unknown etiology, with a base continuous to the original bone and which seems to have a nodular, flat, or pedunculate protuberance located on the alveolar surface of the jaw bone.[167] A small number of cases of buccal exostosis developing secondary to soft tissue graft procedures (free gingival graft) have been reported in periodontal literature.[168–173] The etiologic factors of buccal

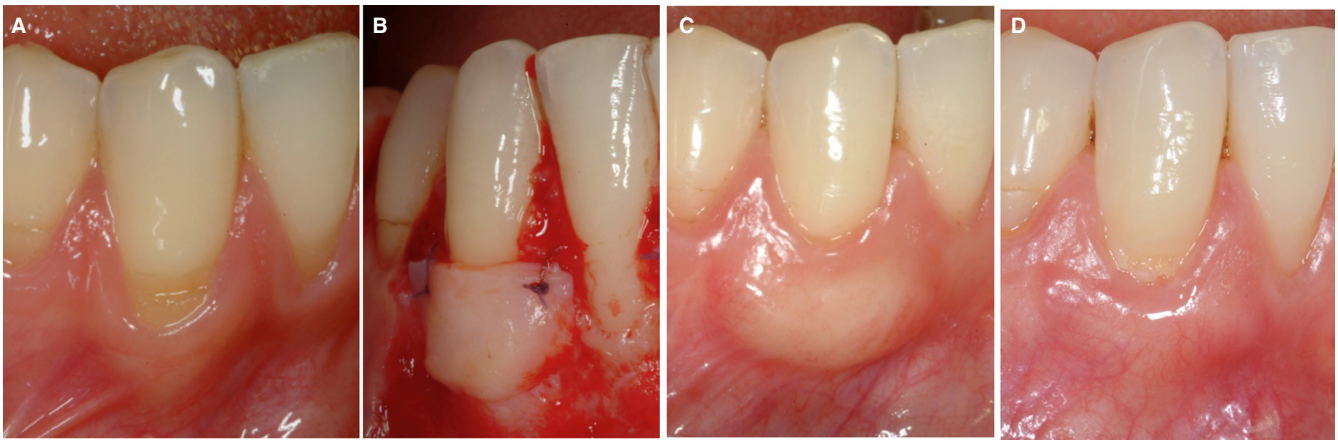


FIGURE 26 A-C, Performance of periodontal plastic surgery (coronally advance flap plus connective tissue graft) in this mandibular right canine affected by gingival recession. D, Several years later, an external root resorption occurred at the cervical area of the tooth.

exostosis are unclear, but all previous reports have been unanimous in suggesting that periosteal trauma seems to be associated with their development.[168–173] Histologic examination revealed osseous enlargements compatible with the diagnosis of exostoses at two reentry procedures. Usually, these manifestations do not represent a real issue for patients unless the exostosis grows so much that it becomes a source of discomfort; in said case, a surgical procedure to remove the exostosis would be necessary.

Despite being an infrequent finding, the clinical implication of exostosis following a gingival graft procedure is that it is a benign condition that must be identified and differentiated from a malignant tumor, such as osteosarcoma.[174] Corroboration of treatment along with palpation, horizontal sounding, and an occlusal radiographic view will help the practitioner establish a correct diagnosis and give the patient reassurance.[171]

4.12 | Cyst-like formation

The use of connective tissue grafts has been correlated with the occurrence of cyst-like formations a few months or years after the surgery. This complication usually appears as a small fistula from which, following the application of pressure on the facial aspect of the gingiva, a thick and white exudate may emerge (Figure 29).

A few cases have been described in the literature[175–180] in which the cyst-like formations have been biopsied and analyzed histologically. The majority of the studies[176–179] have attributed the origin of these lesions to epithelial remnants embedded under the overlying flap. On the other hand, two case reports[175–180] placed the fault on deep epithelial projections in the connective tissue graft, which can create a cyst-like space when the graft is used in association with a covering flap.

When the harvesting techniques adopted entail a graft with an epithelial layer, it is crucial to thoroughly remove the superficial epithelium extraorally using a new blade, adequate light, and magnification. As a matter of fact, a recent histologic study[181] revealed that, despite the efforts to carefully remove the epithelial tissue using a microscope (10×), small remnants were still present in all samples in different proportions.

In our clinical experience, the cyst-like formations are more frequent when the graft has been harvested from the anterior palate, due to the presence of rugae and epithelial invaginations extending into the lamina propria. However, they are usually self-limiting and not painful or uncomfortable for patients. A localized lesion can be drained with soft digital pressure, and it is unlikely to recur. Persistence of exudate might require some form of gingivoplasty based on the extension of the lesion, keeping in mind that this can cause graft exposure and diminishing the esthetic outcome.

4.13 | Residual hypersensitivity

One of the primary goals of root coverage procedures is the resolution of dentin hypersensitivity due to root exposure.[2] Despite the

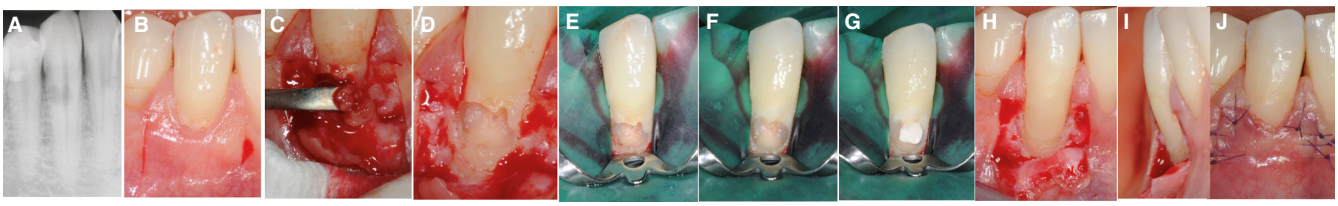


FIGURE 27 Surgical-restorative approach for the treatment of invasive cervical root resorption. A, Radiographic evaluation of the lesion showing an irregularly shaped radiolucent area at the cervical level. B-I, The treatment involved the elevation of a trapezoidal mucoperiosteal flap (B), granulation tissue removal (C), and the exposure of the resorbed area (D); field isolation with a rubber dam (E), recontouring of the lesion borders using burs (F), application of a thin layer of a liner to protect the pulp (G), restoration of the cavity with flowable composite (H), and polishing of the restoration (key aspect of this treatment) (I). J, The flap was repositioned using interrupted sutures.

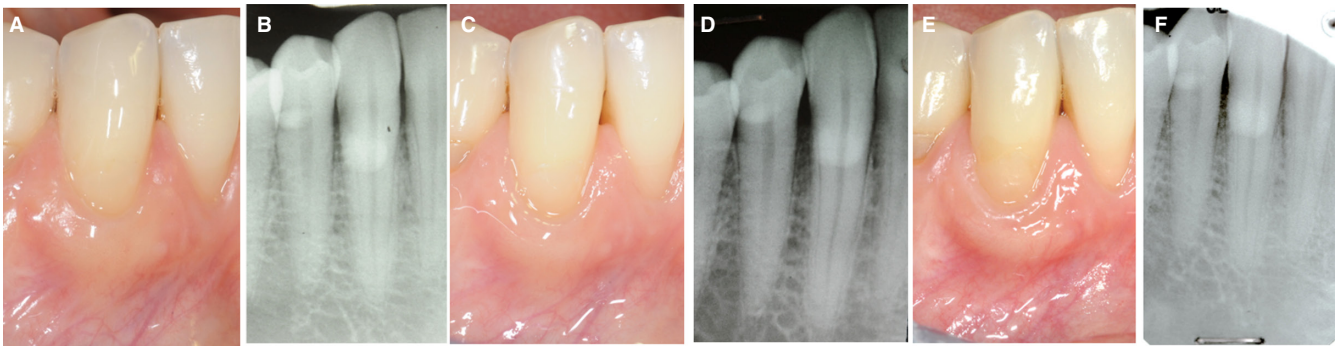


FIGURE 28 Clinical and radiographic appearance after the surgical-restorative approach showing tremendous soft tissue stability together with tooth vitality. A, B, After 1 year. C, D, After 3 years. E, F, After 5 years

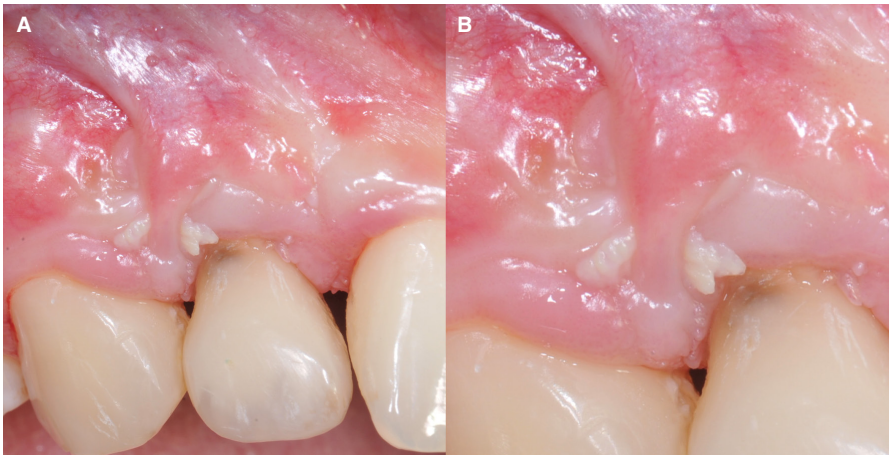


FIGURE 29 A, Clinical manifestation of a cyst-like formation characterized by the emergence of a thick and white exudate at the level of the grafted site. B, Close-up view

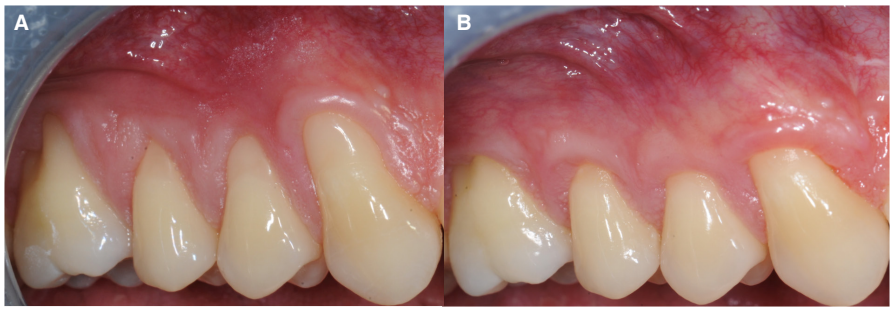


FIGURE 30 A, Multiple gingival recessions affecting the first sextant in a patient with esthetic and hypersensitivity complaints. B, Six months after surgery (coronally advanced flap and site-specific adjunction of connective tissue graft), despite the improvement of the gingival recession's appearance, root exposure is still visible in all the treated teeth.

enormous quantity of randomized clinical trials available in the literature regarding the treatment of gingival recessions, according to a systematic review published by Douglas de Oliveira et al,[182] only nine trials evaluated the influence of root coverage procedures on cervical dentinal hypersensitivity. In that review, a reduction in cervical dentinal hypersensitivity was reported with a mean percentage of 77.83%; however, it was concluded that these results must be viewed with caution because most of the studies had a high risk of bias, and cervical dentinal hypersensitivity was assessed as a secondary outcome.

The scarcity of evidence regarding residual hypersensitivity is likely attributable to the lack of a standardized protocol for evaluating this clinical condition, since it is not yet possible to state whether some methods are more valid than others.[182]

In the recent World Workshop AAP-EFF, it has been underlined that there is not enough evidence to conclude that surgical root coverage procedures predictably reduce cervical dentinal hypersensitivity.[35] None of the nine clinical trials included in the Douglas de Oliveira et al[182] review performed a correlation test between hypersensitivity and percentage of root coverage or degree of gingival recession. Thus, one should not exclude that the reduction in hypersensitivity could also be explained by other factors, such as brushing or the placebo effect.[35]

Generally, residual dentinal hypersensitivity after gingival recession treatments might be due to incomplete root coverage with consequent exposure of dentinal tubuli to the oral cavity. In the case of minimal remaining recession, clinicians might opt for the use of desensitizers or placement of composite restorations to address the issue. More extreme cases of incomplete coverage or recession recurrence normally require surgical reintervention, after 4-6 months, to settle the patient's complaint.

4.14 | Incomplete root coverage

All of the complications, side effects, and treatment errors reported above might result in either partial or no coverage of the gingival recession (Figure 30).

Complete root coverage is expected to solve the recession with the gingival margin located at or 1 mm coronally to the cemento–enamel junction.

Several systematic reviews[5,6,8] have confirmed the superiority of coronally advanced flap plus connective tissue graft compared with other procedures in terms of root coverage percentage. Furthermore, a recent systematic review showed that connective tissue graft–based techniques result in higher patient satisfaction scores than flaps alone. This finding is most likely related to the superior recession reduction and complete root coverage that connective tissue graft and connective tissue graft plus enamel matrix derivative can achieve over treatment with flap alone.[64]

According to Kim et al,[132] partial root coverage might not represent an esthetic issue from the patient's perspective. In that study, subjects considered the result to be "very good to excellent" when the mean percentage of root coverage was 80.2%.[129] This tells us that patients are not always significantly influenced by the percentage of root coverage but rather more by soft tissue integration variables (color and texture).

On the other hand, according to Zucchelli et al,[39] residual root exposure, being of a different color (yellow dentin) than the white of the enamel, might be critical in terms of a successful esthetic evaluation of root coverage as it represents the most visible area during smiling. In this study as well, the difference in color was more critical than the apicocoronal level of the soft tissue margin for a successful esthetic evaluation of root coverage from both professional and patient points of view.

Partial and incomplete root coverage should be handled according to the patient's request and complaints. In the case of partial root coverage due to an incorrect evaluation of maximum root coverage[30,32] a composite restoration is needed to compensate for the uncovered root; when treatment errors or complications (intra- and postoperative) determine partial or incomplete root coverage, a second surgery is recommended to reach the ideal results.

5 | CONCLUSIONS

In recent decades, root coverage procedures have become very common in daily practice. As with any surgical procedure, patient morbidity can be highly influenced by a number of factors, such as local and systemic conditions, as well as by the skill and knowledge of the clinician performing the surgery. Proper patient evaluation and site diagnosis can help avoid many undesirable outcomes. When performing the surgery, the use of anesthetic with vasoconstrictor is advised in order to reduce intraoperative bleeding and have a clear visual field. Specific training is required for the execution of these plastic procedures, but the main technical errors to avoid during flap management are correlated with its thickness, extension, and passivity; positioning the graft at the level of the cemento–enamel junction is required for an esthetic outcome (and will also prevent its exposure); when suturing, tight flap adaptation and first intention wound closure without any residual tension will prevent flap dehiscence and early flap shrinkage. Regarding the postoperative phase, locally applied cold therapy together with the prescription of anti-inflammatory drugs and analgesics are encouraged to reduce swelling and pain; patients should be motivated to carefully follow home-care instructions, since these play a crucial role during the early stages of healing and for the maintenance of the outcome. Even if additional findings such as cyst-like formations, exostosis, or external root resorption are fairly rare, the clinician should keep them in mind as possible complications over time.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript.

DATA AVAILABILITY STATEMENT

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

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