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Periodontal plastic surgery

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Mucogingival therapy is a general term used to describe periodontal treatment involving procedures for the correction of defects in the morphology, position and/or amount of soft tissue and underlying bone support around teeth and implants (12). At the beginning, 'mucogingival surgery', introduced by Friedman in 1957 (69), included surgical procedures designed to preserve gingival tissue, remove aberrant frenal or muscle attachments and increase the depth of the vestibule. Frequently, however, this term was used to describe certain pocket elimination approaches. Therefore, in 1993, Miller (132) introduced the term 'periodontal plastic surgery', accepted by the international scientific community in 1996, which was defined as 'surgical procedures performed to prevent or correct anatomic, developmental, traumatic or disease-induced defects of the gingiva, alveolar mucosa or bone' (203). This definition includes various soft- and hard-tissue procedures aimed at gingival augmentation, root coverage, correction of mucosal defects at implants, crown lengthening, gingival preservation at ectopic tooth eruption, removal of aberrant frena, prevention of ridge collapse associated with tooth extraction and augmentation of the edentulous ridge. This paper focuses on gingival recession defects, their diagnosis and prognosis and the surgical procedures for root coverage.

Etiology of gingival recessions

The gingival margin is clinically represented by a scalloped line that follows the outline of the cemento–enamel junction, 1–2 mm coronal to it. Gingival recession is an apical shift of the gingival margin with exposure of the root surface to the oral cavity (205) (Fig. 1). Gingival recession is often found in populations with good oral hygiene (173, 177), when it is most commonly located at the buccal surfaces (117) and may be associated with wedge-shaped defects in the cervical area of one or more teeth (173). However, gingival recession is also found in populations with poor standards of oral hygiene in which it may affect other tooth surfaces (16, 117). Recession may exist in the presence of normal sulci and nondiseased interdental crestal bone levels, or it may occur as part of the pathogenesis of periodontal disease during which alveolar bone is lost. One etiological factor that may be associated with gingival recession is a pre-existing lack of alveolar buccal bone at the site (202) (Fig. 1). These deficiencies in alveolar bone may be developmental (anatomical) or acquired (physiological or pathological) (72).

Anatomical factors

Anatomical factors that have been related to gingival recession include fenestration and dehiscence of the alveolar bone, abnormal tooth position in the arch, an aberrant path of eruption of the tooth and the shape of the individual tooth (7). These anatomical factors are inter-related and may result in an alveolar osseous plate that is thinner than normal and that may be more susceptible to resorption. Anatomically, a dehiscence may be present because of the direction of tooth eruption or as a result of other developmental factors, such as buccal placement of the root relative to adjacent teeth, so that the cervical portion protrudes through the crestal bone (119). One surgical study found a correlation between gingival recession and bone dehiscence (21). A correlation between the pattern of eruption and gingival recession has also been suggested (134). Dehiscence may be present where the buccolingual thickness of a root is similar to or exceeds the crestal bone thickness (144). The same authors postulated that individuals with morphological biotypes characterized by narrow, long teeth are more prone to dehiscences than are individuals with broad, short teeth. Where gingival recession has developed, the underlying presence of dehiscences may be considered, and possibly discovered during flap procedures.

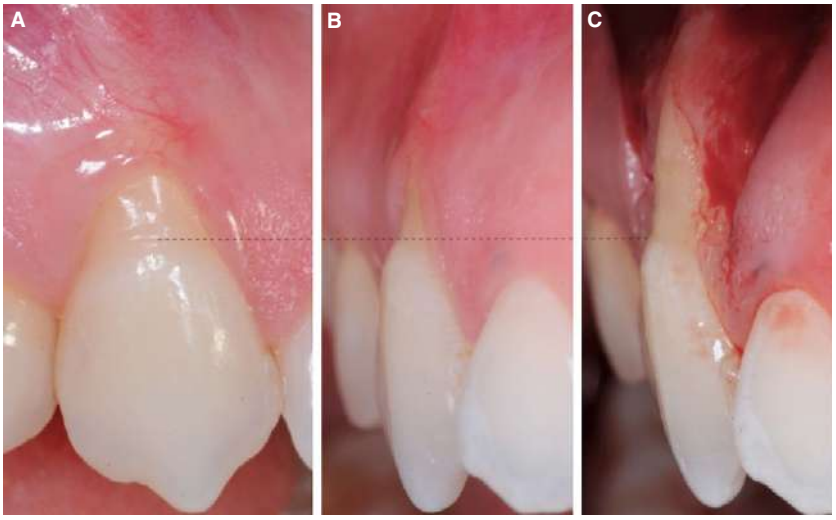

Fig. 1. Gingival recession and bone dehiscence. (A) Gingival recession extending from the cemento–enamel junction (dotted line) to the soft-tissue margin. (B) Gingival recession in the lateral view: the distinction between the anatomic crown and the root (cemento–enamel junction) becomes more evident. (C) Bone dehiscence (from the cemento–enamel junction to the buccal bone crest) associated with gingival recession.

Localized gingival recession may be associated with the position of the teeth on the arch (106, 144). The position in which a tooth erupts through the alveolar process affects the amount of gingiva that will be established around the tooth. If a tooth erupts close to the mucogingival line there may be very little, or no, keratinized tissue labially and localized recession may occur (214). In the developing dentition of preteenage children, buccal displacement of the lower incisors is common and is often associated with gingival recession. Follow-up studies reveal spontaneous reversal of recession as the child matures (13).

Physiological factors

Physiological factors may include the orthodontic movement of teeth to positions outside the labial or lingual alveolar plate, leading to dehiscence formation (105, 206) that may act as 'locus minoris resistentiae' for gingival recession development (172, 206). The gingival recession may appear as a deep and narrow lesion, similar to a 'Stillman cleft', in which domiciliary oral hygiene becomes very difficult to perform, and bacterial or viral infection may induce the formation of a buccal probing pocket of sufficient depth to reach the periapical environment of the tooth. Sometimes a delayed diagnosis is made only when an endodontic abscess occurs.

The volume of the facial soft tissue may be a factor in predicting whether gingival recession will occur during or after active orthodontic treatment. A thin gingiva may be a greater risk factor for progression in the presence of plaque-induced inflammation or toothbrushing trauma (206). Therefore, the active orthodontic movement of the teeth outside the alveolar bone may be considered as an etiological factor. When, during the postorthodontic retention phase, wide and deep multiple gingival recessions occur, it is toothbrushing trauma that acts as an etiological factor on gingival tissue that has been thinned as a result of tooth malposition (buccal dislocation). In such a clinical situation, orthodontic therapy acts as a predisposing factor for gingival recession. Sometimes, isolated deep gingival recessions occur in the lower incisors a few years after orthodontic therapy. Common characteristics associated with these gingival defects are the presence of a round-wire lingual-bonded retainer from canine to canine, a different axial (facial–lingual) inclination of the affected tooth with respect to the adjacent incisors and the presence of inflammatory tissue lateral to the root exposure (Fig. 2). In such a case, the etiological factor can be found in a patient's chronic habits, such as fingernail biting, digit sucking, or sucking on objects such as pens, pencils or toothpicks, that exert continuous pressure on the biting edge of the affected tooth (Fig. 2). As any lingual-crown movement is prevented by the round-wire lingual-bonded retainer, the applied force leads to buccal displacement of the root, bone dehiscence and gingival recession.

Pathological factors

Toothbrushing

Toothbrushing is commonly associated with gingival recession and partly explains the correlation between low plaque levels found at sites of recession (2). Trauma can be caused by 'improper toothbrushing' or by a number of potentially confounding variables, such as pressure, time, bristle type and the dentifrice used (108, 164). Clinical signs of gingival recession caused by toothbrushing are soft-tissue ulcers (with-

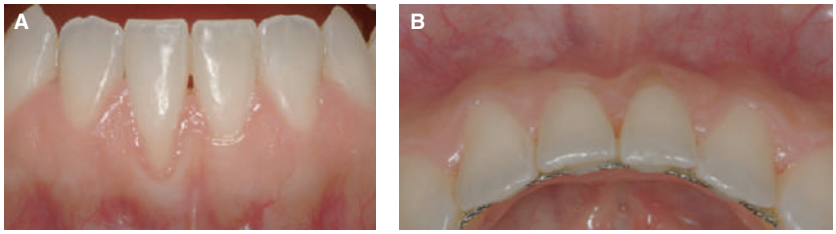

Fig. 2. Postorthodontic gingival recession. (A) Buccal view: note the presence of inflamed, red, highly vascularized tissue lateral to the deep root exposure. (B) Occlusal view: note the presence of the round-wire lingual-bonded retainer from canine to canine and the different axial buccal–lingual inclination of the affected tooth with respect to the adjacent incisors.

out pain) and hard-tissue cervical abrasions (noncarious cervical lesions). Sometimes, soft-tissue trauma may destroy all keratinized gingival tissue. The cervical abrasions are caused by continued mechanical trauma after recession manifestation.

Improper flossing techniques

Flossing trauma can contribute to tooth abrasion and gingival injury (1, 66, 74). These lesions often occur in highly motivated patients who have not been properly instructed in the technique of flossing. Diagnosis of these injuries can often be confirmed by asking patients to demonstrate their oral hygiene procedures (200). The initial injury may appear as an acutely inflamed, ulcerated linear or V-shaped cleft that is symptomatic (74, 87) (Fig. 3). Chronic lesions are often asymptomatic and may not appear to be ulcerated or clinically inflamed. The clefts may traverse the width of the interdental space and extend into the adjacent facial and lingual gingivae. At the histological level, gingival clefts are often lined by stratified squamous epithelium. The base of the cleft may have a bifurcated appearance and exhibit varying degrees of epithelialization (87). Often patients use a flossing technique with a 'sawing' motion (126) while advancing the floss apically into the gingival crevice (200). When flossing trauma is involved, superficial gingival tissue clefts are 'red' because the injury is confined within connective tissue. In this case the lesion is reversible: flossing procedures have to be stopped for at least 2 weeks and chemical plaque control (i.e. chlorexidine rinses) only should be performed (Fig. 3). If the cleft appears 'white' the whole connective tissue thickness is involved and the radicular surface becomes evident; in this case the gingival lesion is irreversible (87, 140) (Fig. 3).

Perioral and intraoral piercing

Piercing of the tongue and perioral regions is becoming an increasingly popular expression of so-called body art (79, 126). Tongue piercing has been directly related to dental and gingival injuries on the lingual aspect of the anterior lower teeth (24, 37), and buccal gingival recession may occur in subjects in whom the lip stud is located such that it can traumatize the gingiva (37, 63). Frequently, the lingual gingival lesion is

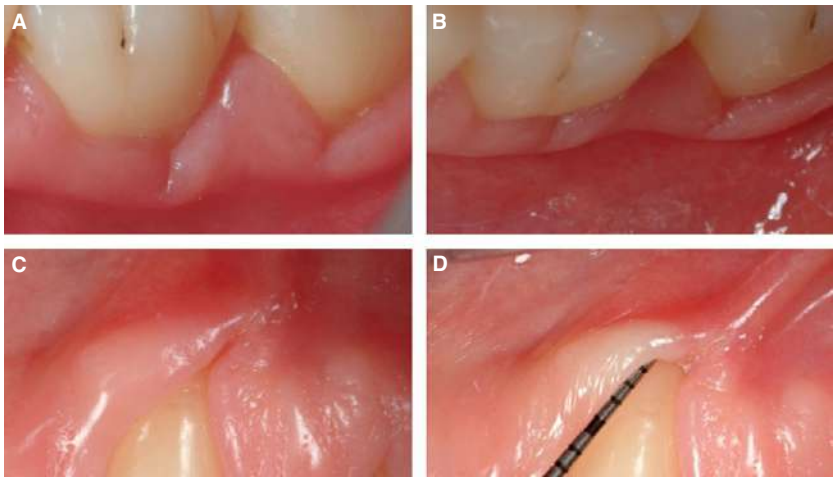

Fig. 3. Gingival cleft. (A, B) 'Red cleft': the interruption of the soft-tissue margin is not full thickness. The lesion can be reversed by interrupting the trauma. (C, D) 'White cleft': the root surface is evident at the bottom of the fissure. Re-epithelization of the lesion is complete.

narrow and thin and plaque control is difficult to perform; when particularly deep, lingual recession can be associated with a probing pocket depth that can reach the periapical region. Removal of the stud is desirable to eliminate the etiological factor (175). Further therapy (such as mucogingival surgery) (179) may be necessary when keratinized tissue is lost and the periodontal attachment compromised.

Direct trauma associated with malocclusion

Class II, division two, malocclusions have a deep overbite and often a reduced overjet with retroclination of the upper anterior teeth. In some severe cases this can result in direct trauma to the labial gingiva of the lower anterior teeth or to the palatal marginal gingiva of the upper anterior teeth (97). This may result in indentations in the gingiva and can result in recession at the site (195). In rare cases in young people, the orthodontic/orthognatic management of malocclusion and appropriate toothbrushing can solve gingival recession without the need for surgical interaction.

Partial denture/restorative therapy

Poorly designed or maintained partial dentures and the placement of restoration margins subgingivally may not only result in direct trauma to the tissues (55), but may also facilitate subgingival plaque accumulation, with resultant inflammatory alterations in the adjacent gingiva and recession of the soft-tissue margin (85, 111, 147). Experimental and clinical data suggest that the thickness of the marginal gingiva (182), but not the apico–coronal width of the gingiva (64), may influence the magnitude of recession taking place as a result of direct mechanical trauma during tooth preparation and bacterial plaque retention. If gingival recession is caused only by trauma from partial dentures, complete root coverage is possible by mucogingival surgery; however, if recession is caused by interdental attachment loss during tooth preparation, root coverage is not achievable. In both cases a new partial denture is suggested.

Bacterial plaque

Gingival recession may be caused by localized accumulation of bacterial plaque on the buccal surface of the tooth (17, 117, 168, 195, 196). This should not be confused with gingival recession caused/associated with periodontal disease. In the latter, bacterial plaque (specific periodontal pathogens) causes connective tissue attachment loss that may clinically manifest with gingival recession not only at buccal surfaces but also at the interproximal tooth surfaces. Bacterial plaque-induced gingival recessions are caused by plaque accumulation localized to the buccal surface with no severe interdental attachment loss; thus, they can be successfully treated with root-coverage procedures. Patients with bacterial plaque-induced recessions must be motivated on the importance of oral hygiene, and mucogingival surgery must not be performed until good plaque control has been achieved. The presence of microbial deposits on the exposed root surface and/or clinical signs of inflammation in the surrounding tissues are useful for reaching the correct diagnosis. Buccal probing pocket depths apical to the root exposure are frequently associated with bacteria-induced gingival recessions.

Herpes simplex virus

Gingival recession may be associated with herpes simplex virus type 1. The lesions consist of multiple vesicles that rupture, rapidly giving rise to ulcers (62, 68). They are often accompanied with pain and sometimes with fever and regional lymphadenopathy. The lesion can be found in all areas of the mouth because of diffusion of the infection with toothbrushing; frequently, associated mucocutaneous lesions can be found. In the early phase ulcers do not involve the gingival margin and it is suggested that toothbrushing is responsible for their evolution (159). In the presence of virus-induced gingival lesions, toothbrushing and dental flossing should be stopped and chemical plaque control (with chlorexidine rinsing) should be performed. Surgical procedures are indicated only if and when gingival recession becomes irreversible.

Classification, diagnosis and prognosis of gingival recessions

Gingival recession can be treated with various surgical procedures, and root coverage can be obtained irrespective of the surgical approach adopted. The most important prognostic factor for root coverage following surgery is the height of the interdental periodontal support (clinical attachment and alveolar bone levels) (131). In the case of a periodontally healthy tooth the papillae completely fills the interdental spaces and there is no clinical attachment loss or bone loss; periodontal probing and intraoral X-ray may be helpful to confirm the healthy condition. Gingival recessions have been classified by Miller (131) into four classes (an illustration of Miller's classification is reported in Fig. 4), according to the prognosis of root coverage. In Class I and Class II gingival recessions, there is no loss of interproximal periodontal

Fig. 4. Miller classification of gingival recession. (A) Class I: the interdental periodontal support is intact and the gingival recession does not reach the mucogingival line. Complete root coverage can be achieved. (B) Class II: the interdental periodontal support is intact and the gingival recession reaches the mucogingival line. Complete root coverage can be achieved. (C) Class III: there is some interdental attachment and bone loss and the gingival recession reaches the mucogingival line. Partial root coverage can be achieved. (D) Class IV: bone and attachment loss are so severe that no root coverage can be accomplished.

attachment and bone, and complete (up to the cemento–enamel junction) root coverage can be achieved. The difference between the two classes lies in the height of the root exposure reaching (Class II) or not reaching (Class I) the mucogingival junction. In Class III gingival recessions, the loss of interdental periodontal support is mild to moderate, and partial root coverage can be accomplished; in addition, tooth/root malposition limits the possible amount of root coverage. In Class IV gingival recessions, the loss of interproximal periodontal attachment (or tooth/root malposition) is so severe that no root coverage is feasible.

Some questions/doubts about the classification of gingival recession, not clarified in Miller's classification, have recently been highlighted (160). One of these doubts relates to the Miller's class of gingival recession (Class I or Class II) extending beyond the mucogingival line, but conserving a small, probable height of keratinized tissue apical to the root exposure (Fig. 5). The distinction, even if not significant from a prognostic point of view, could be useful for selecting the most successful root-coverage surgical approach. Other criticisms of Miller's classification relate to the unclear procedures to ascertain the amount of soft-/hard-tissue loss in the interdental area to differentiate Class III and Class IV (Fig. 6) and the unclear influence of tooth malpositioning (160) (Fig. 7). Cairo et al. (35) recently introduced a new classification system of gingival recessions using the level of interproximal clinical attachment as an identification criterion; they also explored the predictive value of the resulting classification system on final root coverage outcomes following surgery. Three recession types (RT) were identified: class RT1 included gingival recession with no loss of interproximal attachment; class RT2 comprised recession with loss of interproximal attachment less than or equal to the buccal site; and class RT3 showed interproximal attachment loss higher than the buccal site. The results of this study show that the recession type class is a strong predictor of the final recession reduction after different surgical procedures. The authors hypothesized that the level of interproximal clinical

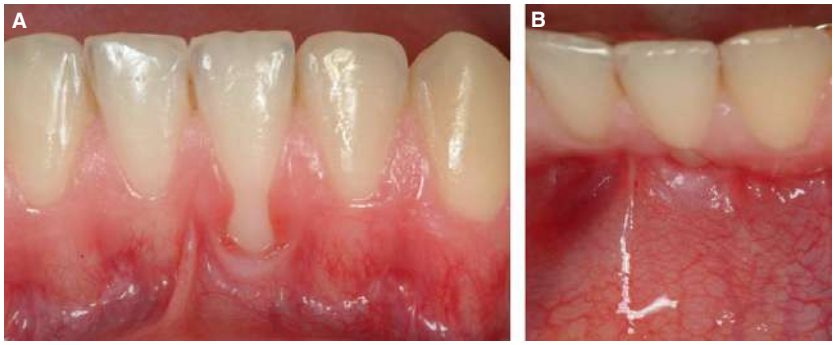

Fig. 5. Criticisms of Miller's classification of gingival recession. (A, B) Distinction between Class I and Class II is not clear for gingival recessions extending beyond the mucogingival line but a small height of probable keratinized tissue is conserved apical to the exposed root.

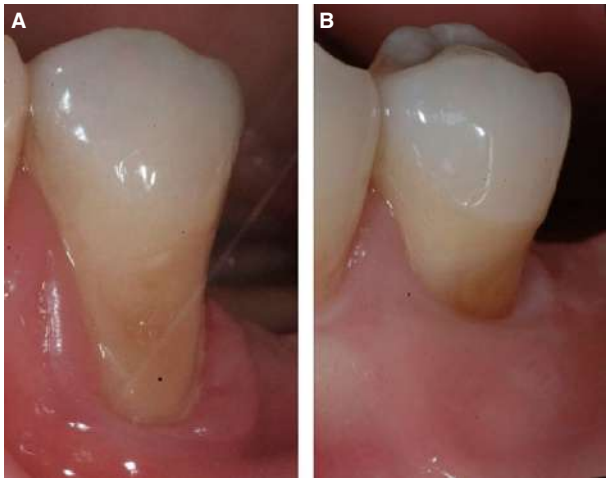

Fig. 6. Criticisms of Miller's classification of gingival recession. (A, B) Distinction between Class III and Class IV: partial root coverage can be accomplished in 'supposed' Class IV gingival recessions.

attachment loss is the coronal limit of the achievable amount of root coverage at the buccal site after surgery. The RT1 class showed a higher mean reduction of recession compared with the RT2 class, highlighting the importance of baseline interproximal clinical attachment loss for the prognosis of gingival recession treatment. The same authors (34) recently published a randomized clinical trial evaluating the adjunctive benefit of connective tissue grafts compared with coronally advanced flaps for the treatment of gingival recession associated with interdental clinical attachment loss the same as or smaller than buccal attachment loss (RT2). They concluded that complete root coverage can be achieved in RT2 affecting the upper anterior teeth with both coronally advanced flap alone and coronally advanced flap plus connective tissue grafts; however, the additional use of a connective tissue graft resulted in a greater number of sites with complete root coverage: >80% of the sites when the baseline amount of interdental clinical attachment loss was ≤3 mm (34). Further longer-term studies are advocated to evaluate root coverage in Miller Class III and Class IV gingival recessions. Another criticism of Miller's classification regards the difficulty of identifying the cemento–enamel junction on teeth affected by gingival recession and noncarious cervical lesions (Fig. 8). Pini-Prato et al. (161) recently proposed a clinical classification of surface defects in teeth associated with gingival recession. Four classes of dental-surface defects in areas of gingival recession were identified on the basis of the presence (Class A) or absence (Class B) of the cemento–enamel junction and of the presence (Class+) or absence (Class−) of surface discrepancy (a step). Of 1010 exposed root surfaces, 144 (14%) showed an identifiable cemento–enamel junction associated with a root surface step (Class A+), 469 (46%) showed an identifiable cemento–enamel junction without any associated step (Class A−), 244 (24%) demonstrated an unidentifiable cemento–enamel junction with a step (Class B+) and 153 (15%) showed an unidentifiable cemento–enamel junction without any associated step (Class B−). According to the authors, the classification of dental surface defects in conjunction with the classification of periodontal tissues is useful for reaching a more precise diagnosis in areas of gingival recession, and the condition of the exposed root surface may also be important for the prognostic evaluation of mucogingival surgery. In the literature (169, 203), predictability of root coverage was measured in terms of the mean percentage of root coverage (indicating the percentage of the root exposure covered with soft tissues) and the percentage of complete root coverage (showing the percentage of teeth with the soft-tissue margin covering the cemento–enamel junction). For the correct evaluation of both of these parameters, it is necessary to recognize the cemento–enamel junction, which anatomically separates the crown from the root, on the tooth with the recession defect. Therefore, the clinical healing pattern only of those gingival recessions in which the cemento–enamel junction is clinically detectable could be evaluated in terms of percentage and/or complete root coverage. When the cemento–enamel junction is not recognizable, it is no longer possible to measure the depth (and width) of the recession and/or to assess the efficacy of a surgical technique in terms of root coverage, as a result of the lack of the reference parameter (226). Furthermore, other tooth/gingival

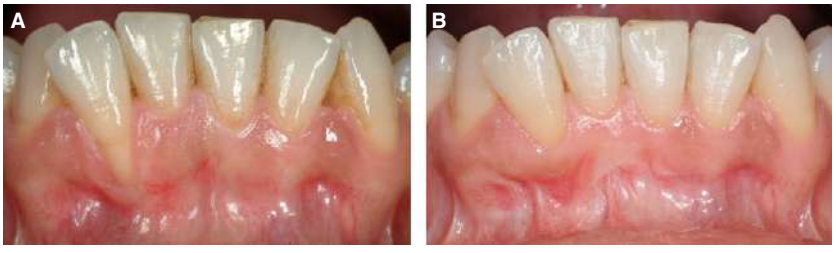

Fig. 7. Criticisms of Miller's classification of gingival recession. (A, B) The role of tooth malposition in preventing complete root coverage: complete root coverage can be accomplished in 'supposed' Class III gingival recession (caused by buccal dislocation of the root).

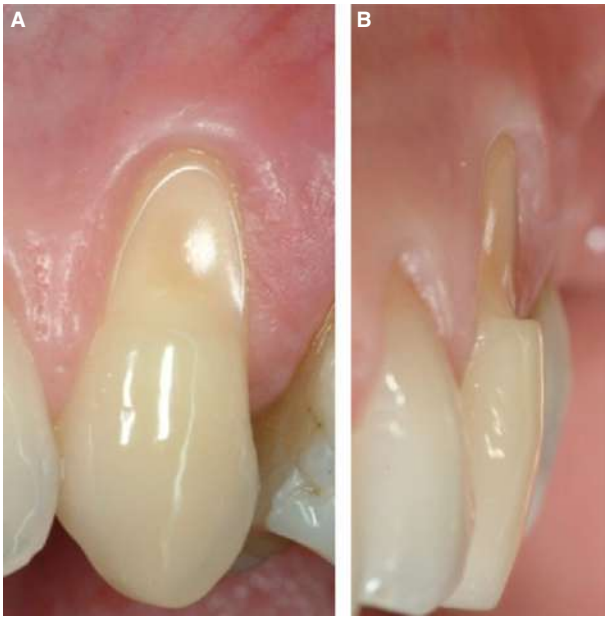

Fig. 8. Criticisms of Miller's classification of gingival recession. (A, B) A noncarious cervical lesion may hide the cemento–enamel junction. When the cemento–enamel junction is not recognizable, it is no longer possible to measure the depth (and width) of the recession, to assess the prognosis and to evaluate the treatment outcome in terms of root coverage.

local conditions that may limit complete root coverage, even in the presence of an intact interdental periodontal support, have recently been suggested, such as loss of interdental papillae, tooth rotation, tooth extrusion and occlusal abrasion (226).

The difficulty of identifying the anatomic cemento–enamel junction at a tooth with noncarious cervical lesions, and the presence of anatomic or clinical conditions limiting root coverage even in Class I and Class II gingival recessions, stimulated clinicians to predetermine the level of root coverage (i.e. the level at which the soft-tissue margin will be stable after the healing process of a root coverage surgical procedure). Predetermination of root coverage was performed by Aichelmann-Reidy et al. (4) in a comparative study on the treatment of single-type gingival recession defects. In this study the treating periodontist made a clinical determination of the expected amount of root coverage, based on clinical experience and clinical conditions, on the test teeth and adjacent areas. Factors such as tooth position, root prominence and recessions on adjacent teeth were taken into account in making the subjective clinical decision. However, in this article, there was no mention of how the expected amount of root coverage was calculated. More recently, a method to predetermine the level of root coverage, based on calculation of the ideal height of the anatomic interdental papilla, was demonstrated to be reliable in predicting the position of the soft-tissue margin 3 months after root-coverage surgery (224). This level was depicted as a line that should coincide with the anatomic cemento–enamel junction when this was not clinically detectable on the tooth with Miller Class I or Class II gingival recessions, or would be more apical than the anatomic cemento–enamel junction when the ideal anatomic conditions to obtain complete root coverage were not fully represented (i.e. Miller Class III gingival recession). This line was described as the 'line of root coverage' or the 'clinical cemento–enamel junction'. The ideal height of the papilla in a tooth with gingival recession was defined as the apical–coronal dimension of the interdental papilla capable of 'supporting' complete root coverage (224, 226). In a nonrotated/malpositioned tooth, the ideal height of the papilla was measured at the same tooth with gingival recession, whereas in a rotated/malpositioned tooth it was measured at the level of the homologous, contralateral tooth. The ideal height of the papilla was measured as the distance between the point at which the cemento–enamel junction crosses the facial mesial–distal line angle of the tooth (the cemento–enamel junction angular point) and the contact point. The cemento–enamel junction angular point is easily identifiable, even in a tooth with noncarious cervical lesions, by elevating the interdental soft tissues (with a probe or small spatula) and searching for the interdental cemento–enamel junction. Once the ideal papilla was measured, this dimension was replaced apically, starting from the tip of the mesial and distal papillae of the tooth with the recession defect. The horizontal projections on the recession margin of these measurements allowed the identification of two points that were connected by a scalloped line, representing the 'line of root coverage' (Fig. 9). The maximal level of root coverage was considered as the most apical extension of the line of root coverage (221, 224, 226). Predetermination of the maximal level of root coverage was used to select the treatment approach for noncarious cervical lesions associated with gingival recessions: root coverage surgery was performed when the maximal level of root coverage was located at the level of, or coronal to, the most coronal step of the noncarious cervical lesions area: the need for a connective tissue graft as an adjunct to the coronally advanced flap increases with increasing depth of the noncarious cervical lesions and the proximity of the maximal level of root coverage to the coronal step of the abrasion defect. A restorative therapy before mucogingival surgery was indicated when the maximal

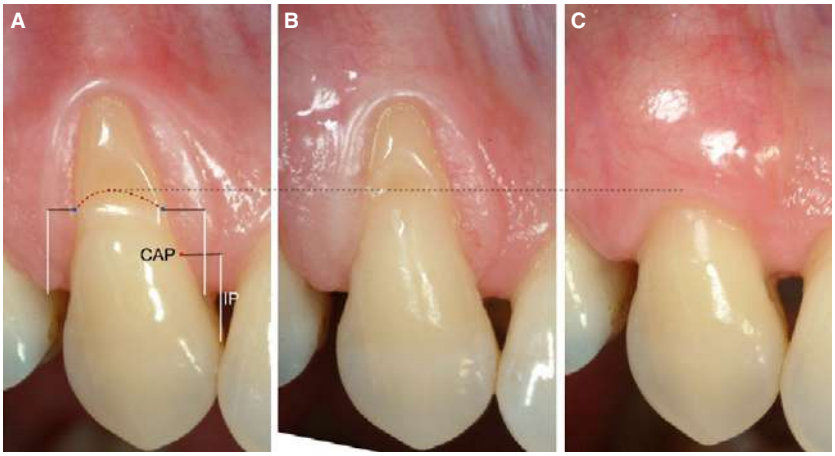

Fig. 9. Predetermination of root coverage. (A) The ideal papilla is measured as the distance between the cemento–enamel junction angular point and the contact point. This distance is replaced apically starting from the tip of the papillae. The horizontal projections of these measurements allow the identification of two points (blue points) that are connected by the 'line of root coverage'. (B) This line can be used as a guide for composite lengthening of the clinical crown. (C) Three months after root-coverage surgery the soft-tissue margin is located at the level of, or slightly coronal to, the composite filling. Esthetically 'complete' root coverage can be achieved, even in Class III gingival recessions. CAP, cemento-enamel junction angular point; IP, interproximal.

level of root coverage was located within the abrasion defect (using the restorative–mucogingival approach). Conservative treatment (with or without access flap surgery) was performed when the maximal line of root coverage was located at the level or apical to the most apical extension of the abrasion area (221).

Indications for root coverage surgical procedures

The treatment of gingival recession defects is indicated for esthetic reasons, to reduce root hypersensitivity and to create or augment keratinized tissue (36, 48, 78, 136, 169, 203, 205). Indications for root coverage procedures are root abrasion/caries and the inconsistency/disharmony of the gingival margin.

Esthetic reasons

The main indication for treatment of gingival recessions is patient demand. The excessive length of the tooth/teeth (i.e. those with recession) may be evident when smiling and sometimes during phonation. Esthetic 'shortening' of the tooth can only be accomplished with root coverage surgical procedures.

Hypersensitivity

Sometimes the patient complains of hypersensitivity to thermal stimuli (especially to cold) at the level of teeth affected by gingival recession. This is a cause of discomfort and/or pain and can make proper oral hygiene very difficult to perform. If there is no concomitant esthetic complaint related to the excessive tooth length, a less invasive (and patient-appreciated) treatment is the local application of chemical desensitizing agents. If this is not effective, a restorative treatment (composite fillings) may be performed. If and when dentine hypersensitivity is associated with a patient complaint about esthetics, treatment of gingival recession should be surgical or combined restorative–surgical (e.g. a combined restorative–mucogingival approach).

Keratinized tissue augmentation

The indication for treatment of gingival recession may also result from the site-specific patient difficulty/inability to maintain adequate plaque control because of the deep, narrow nature of the recession defect or the absence of keratinized tissue.

Root abrasion/caries

The indication for treatment of gingival recession may also derive from the concomitant presence of root demineralization/caries or deep abrasion defects that can cause hypersensitivity and/or may render the patient's plaque control difficult. Treatment of radicular caries/abrasion associated with gingival recession can be surgical or combined restorative–surgical, depending on the potential to cover with soft

tissue, or not cover, the area affected by abrasion or caries (see the prognosis of root coverage) (205).

Inconsistency/disharmony of gingival margin

Inconsistency/disharmony of the gingival margin may be caused by the morphology of the gingival recession, even in the absence of dentin hypersensitivity, which may prevent the patient performing an effective toothbrushing technique. This is especially true when gingival recessions are isolated and deep, when they are very narrow with triangular-shape vertices (the so-called 'Stillman cleft') or when they extend beyond the mucogingival junction. The only feasible treatment is root coverage surgery.

Root coverage surgical procedures

The ultimate goal of a root coverage procedure is complete coverage of the recession defect with a good appearance related to the adjacent soft tissues and minimal probing depth following healing (36, 48, 49, 131, 169).

Surgical procedures used in the treatment of recession defects may basically be classified as follows (115).

Pedicle soft-tissue graft procedures:

- Rotational flap procedures (laterally sliding flap, double papilla flap, oblique rotated flap);
- Advanced flap procedures (coronally repositioned flap, semilunar coronally repositioned flap);
- Regenerative procedures (with barrier membrane or application of enamel matrix proteins)

Free soft-tissue graft procedures:

- Epithelialized graft;
- Subepithelial connective tissue graft

The international literature has thoroughly documented that gingival recession can be successfully treated using several surgical procedures (205), irrespective of the technique utilized, provided that the biological conditions for accomplishing root coverage are satisfied (no loss in height of interdental soft and hard tissue) (131).

The selection of one surgical technique over another depends on several factors, some of which are related to the defect (the size and number of the recession defects, the presence/absence, quantity/quality of keratinized tissue apical and lateral to the defect, the width and height of the interdental soft tissue (papillae), the presence of frenum or muscle pull and the depth of the vestibulum), whereas others are related to the patient (219). The esthetic request and the need to minimize postoperative discomfort are the most important patient-related factors to be considered in the selection of the root coverage surgical approach. Furthermore, the clinician must consider data from the literature in order to select the most predictable surgical approach, among those feasible in a given clinical situation.

In a patient with esthetic requests, pedicle flap surgical techniques (coronally advanced or laterally moved flaps) are recommended if there is adequate keratinized tissue apical or lateral to the recession defect (10, 32, 81, 83, 84, 187, 204). In these surgical approaches the soft tissue utilized to cover root exposure is similar to that originally present at the buccal aspect of the tooth with the recession defect and thus the esthetic result is satisfactory. Furthermore, the postoperative discomfort is minimal as second surgical sites (palate) far from the tooth with the recession defect are not involved.

Conversely, when the keratinized tissue apical or lateral to the gingival defect is not adequate, free graft procedures have to be performed (25, 96, 124, 130, 133, 184, 190). The use of free gingival grafts to treat recession defects in patients with esthetic requests is not recommended because of the poor esthetic outcome and the low root coverage predictability (205). The use of a pedicle flap to cover the graft (i.e. the bilaminar technique) improves the root coverage predictability (by providing an additional blood supply to the graft) and the esthetic result (through hiding the white-scar appearance of the graft and masking the irregular outline of the mucogingival junction that frequently occurs after a free graft procedure) (8, 9, 28, 29, 92, 112, 137, 163, 204). This paper will focus in particular on those surgical procedures that have been reported to be more predictable in achieving root coverage. From a clinical standpoint it can be useful to classify them in root coverage surgical procedures for single and for multiple recession-type defects.

Pedicle soft tissue graft procedure for single recession defects

Coronally advanced flap

The coronally advanced flap procedure is a very common approach for root coverage. This procedure is based on the coronal shift of the soft tissues on the exposed root surface (10, 156). It is the technique of choice for the treatment of isolated gingival recession. It is technically simple, well tolerated by the patient [because the surgical area is limited and does

not require removal of tissue far from the tooth with the gingival recession (palate)] and provides optimal results from an esthetic point of view (Fig. 10). The conditions required to perform the coronally advanced flap are the presence of keratinized tissue, apical to the root exposure, of an adequate height (1 mm for shallow recessions and 2 mm for recessions ≥5 mm) (57, 203) and thickness. The technique was initially described by Norberg (138) and subsequently reported by Allen & Miller (10). Recently, it was modified (57) using a trapezoidal flap design and a split–full–split-thickness flap elevation approach (Fig. 10). This technique resulted in a very high mean percentage (99%) and complete (88%) root coverage at 1 year; these outcomes were similar (59, 204, 217, 218), or even higher (6, 33, 155, 193), than those reported in the literature for other root coverage procedures. The 3-year outcomes showed only a slight decrease compared with those at 1 year: 97% of root coverage and 85% of complete root coverage. A recent systematic review (36) concluded that the coronally advanced flap procedure is a safe and predictable root coverage surgical procedure for the treatment of single type gingival recessions. The mean percentage and the percentage of complete root coverage of the articles comprised in the systematic review (36) are summarized in Table 1. The modified coronally advanced flap (57) technique (Fig. 11) presented some clinical and biologic advantages over the split–full–split-thickness flap elevation (219): the split-thickness elevation at the level of the wide (3 mm) surgical papilla provided anchorage and blood supply to the interproximal areas mesial and distal to the root exposure. Furthermore, the partial thickness of the surgical papillae facilitated the nutritional exchanges between them and the underlying de-epithelialized anatomical papillae and improved the blending (in terms of color and thickness) of the surgically treated area with respect to the adjacent soft tissues. The full-thickness elevation of the soft tissue apical to the root exposure conferred more thickness and some periosteum, and thus better opportunity to achieve root coverage (18) to that portion of the flap residing over the exposed avascular root surface. The more apical split-thickness flap elevation facilitated the coronal displacement of the flap. Although the technique included vertical releasing incisions, these did not result in unesthetic scars. In fact, these incisions were beveled in such a way that the bone and periosteal tissues were not included in the superficial cut and thus did not participate in the healing process. Another important modification of the present surgical technique, with respect to the previously proposed techniques (10, 150, 204), was that the coronal advancement of the flap was not obtained by periosteal incisions, but rather by cutting the muscle insertions included in the thickness of the flap. A 'deep' incision (with the

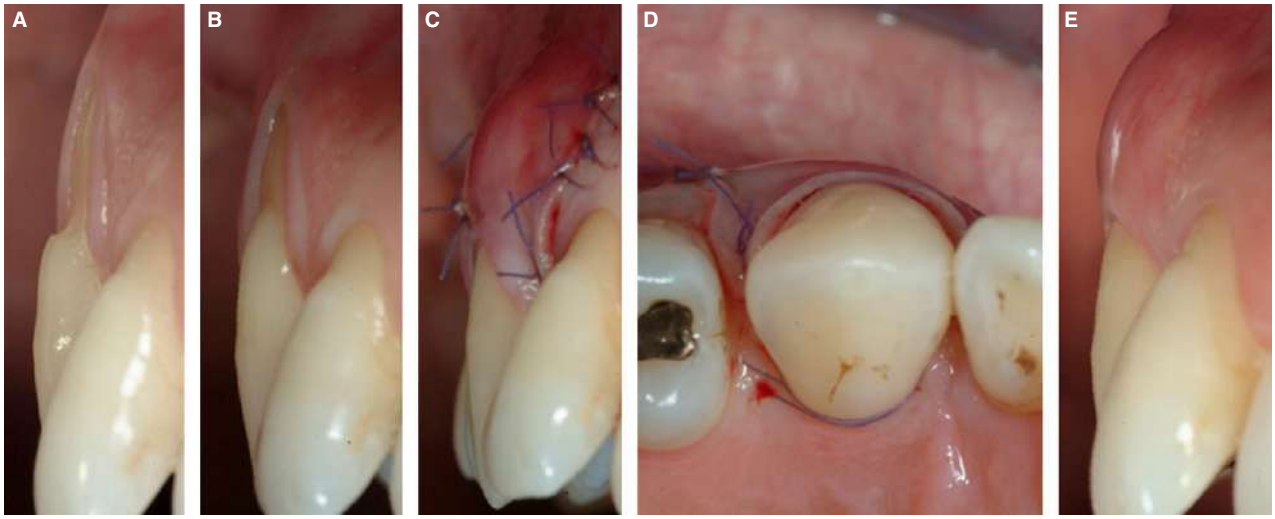

Fig. 10. Predetermination of root coverage. (A) Lateral view of the same tooth shown in Fig. 9. The coronal step of the noncarious cervical lesion cannot be covered with the soft tissues. (B) Enamel plastic and composite restoration finished at the level of the 'line of root coverage'. (C) The flap is coronally advanced to cover in excess the composite profile. Note the thickness of the coagulum that forms between the root surface and the coronally displaced soft tissue. (D) The sling coronal suture anchored to the palatal cingulum permits precise adaptation of the flap marginal tissue to the convexity of the clinical crown restored in composite. There is no space for coagulum exposure. (E) Two years after the root coverage procedure. The increase in buccal soft-tissue thickness, together with the composite filling, provides the treated tooth with good esthetics and a correct emergence profile.

Table 1. Mean root coverage and complete root coverage (%) with coronally advanced flap technique

Study	Flap procedure	Mean root coverage (%)	Complete root coverage (%)
da Silva et al. (54)	Coronally advanced flap	68.8	11.0
P. Cortellini (unpublished data)	Coronally advanced flap	62.0	Not available
Lins et al. (116)	Coronally advanced flap	60.0	Not available
Leknes et al.(114)	Coronally advanced flap	34.0	Not available
Modica et al. (135)	Coronally advanced flap	80.9	58.3
Del Pizzo et al. (59)	Coronally advanced flap	67.0	60.0
Spahr et al. (180)	Coronally advanced flap	86.7	23.0
Castellanos et al. (41)	Coronally advanced flap	62.2	36.3
Pilloni et al. (152)	Coronally advanced flap	65.5	31.2
Woodyard et al. (212)	Coronally advanced flap	67.0	33.3
de Queiroz Cortes et al. (56)	Coronally advanced flap	55.9	23.1
Huang et al. (98)	Coronally advanced flap	83.5	58.3

Fig. 11. Coronally advanced flap. (A, B) Comparison of the smile before and after placement of a coronally advanced flap at the level of the left upper canine. The esthetic outcome was satisfactory for the patient.

blade parallel to the bone) detached the lip muscle from the periosteum and permitted the performance of a 'superficial' incision (with the blade parallel to the lining mucosa) that allowed for coronal advancement of the flap. These incisions minimized lip tension on the flap and permitted passive displacement of the flap soft-tissue margin in a coronal position. A further technical aspect that was considered critical for the success of the modified coronally advanced flap procedure related to the coronal sling suture. The anchorage to the palatal cingulum permits precise adaptation of the keratinized tissue of the flap to the convexity of the crown of the treated tooth. This minimizes exposure of the coagulum, which forms between the soft tissue and the root exposure, to the detrimental microbiological and traumatic agents of the oral environment. The increased stability of the coagulum may play a role in preventing early flap dehiscence and thus favor root coverage. The need for a tight coronal adaptation of the keratinized tissue of the flaps at the time of suturing (Fig. 12C,D) represented another indication (221), together with the esthetic indication, for a composite reconstruction, before surgery, of the convexity of the tooth crown interrupted by the presence of noncarious cervical lesions (Figs 9 and 12).

A large increase in keratinized tissue height was demonstrated after coronally advanced flap surgery in the study by De Sanctis & Zucchelli (57) (Fig. 13): in fact, 3 years after the surgery, the mean increase of keratinized tissue was 1.78 mm, and this increase was greater in sites with deeper recession and a lower amount of residual keratinized tissue at baseline. Very similar results were obtained in a previous study evaluating the 5-year outcomes of the coronally positioned flap for multiple gingival recessions (218). Some hypotheses were made in an attempt to explain the increase of keratinized tissue after coronally

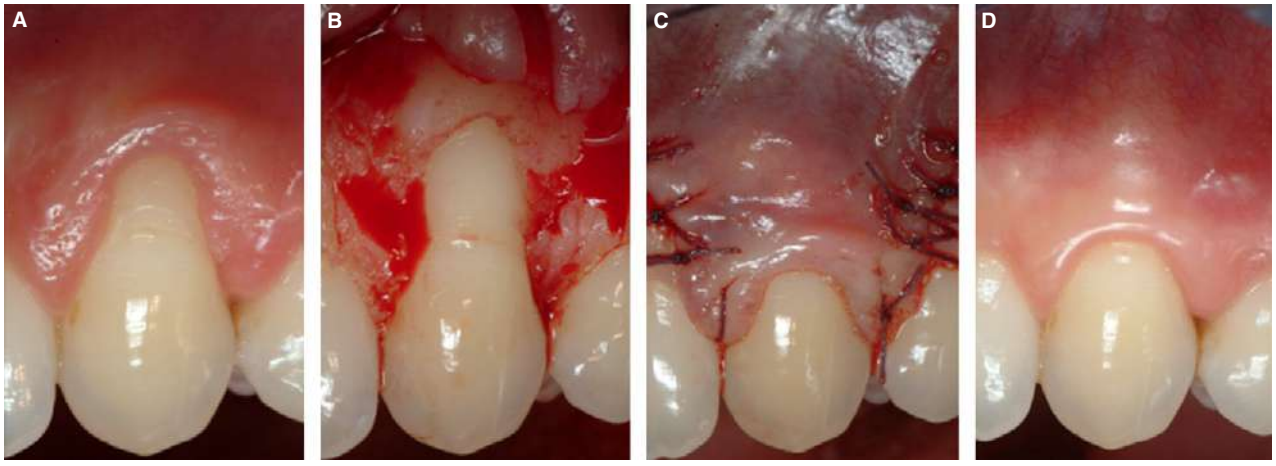

Fig. 12. Coronally advanced flap surgical technique of the tooth shown in Fig. 11. (A) Baseline gingival recession. (B) Trapezoidal split–full–split flap elevation. Note the bone exposure apical to the bone dehiscence. The periosteum has been left in that portion of the flap covering the avascular root surface. There is no bone exposure along the vertical releasing incisions to minimize keloid formation after the healing process. (C) The flap has been coronally advanced and secured with interrupted sutures along the vertical releasing incisions and a coronal sling suture anchored to the palatal cingulum. (D) At 2 years of follow up, complete root coverage and an increase in keratinized tissue height have been accomplished.

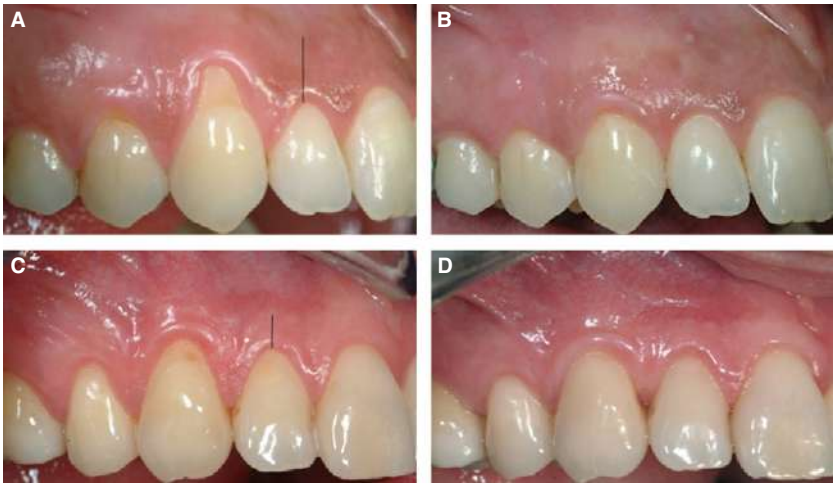

Fig. 13. Increase in keratinized tissue height after placement of a coronally advanced flap in different patient biotypes. (A) Gingival recession in a patient with an apical location of the mucogingival line (compare with healthy tooth, i.e. the lateral incisor). (B) Three years after placement of a coronally advanced flap: the great increase in keratinized tissue height could be ascribed to the tendency of the mucogingival line to regain its genetically determined position. (C) Gingival recession in a patient with a more coronal location of the mucogingival line (see the lateral incisior). (D) Three years after placement of a coronally advanced flap: the small increase in keratinized tissue height could be explained with the lower excursion threat which the mucogingival line had to make to reach the genetically determined position.

advanced flap surgery: the tendency of the mucogingival line, coronally displaced during the surgery, to regain its original, 'genetically determined' position (5); or the capability of the connective tissue, deriving from the periodontal ligament, to participate in the healing processes taking place at the dento–gingival interface (107, 121, 149). The observation that the increase in keratinized tissue height was greater when, before surgery, there was a greater recession depth and narrower residual band of attached gingiva apical to the defects seems to support the hypothesis of the tendency of the mucogingival junction to regain its genetically determined position. In fact, these were the clinical situations in which a greater coronal displacement of the mucogingival line was performed during the surgery. The repositioning of the mucogingival line could also explain the great variability among patients (and studies) in the increase of keratinized tissue height after coronally advanced flap procedures. One can speculate that patient bio-

type might influence the increase in keratinized tissue after surgery: patients with a more apical position of the mucogingival line will experience a greater increase of keratinized tissue height after coronally advanced flap surgery relative to patients with a more coronal location of the mucogingival junction. Randomized comparative clinical trials of different patient biotypes are advocated to test this hypothesis. Recently, Pini Prato et al. (157) evaluated, in a long-term 14-year randomized split-mouth study, the outcomes of two different methods of root-surface modifications (root-surface polishing compared with root planing) used in combination with a coronally advanced flap performed for the treatment of single type gingival recessions. The authors (157) observed that, during the 14-year follow-up period, an apical shift of the gingival margin occurred in 39% of the patients treated in both groups, showing a progressive worsening of the gingival recessions with time. The observed relapse of the soft-tissue defects could be ascribed to a resumption of traumatic toothbrushing habits in patients with high levels of oral hygiene, even if they were included in a stringent maintenance protocol with recall every 4–6 months. Regarding the keratinized tissue width, the results of Pini Prato et al. (157) showed its tendency to decrease over time. The same authors (162) evaluated the outcomes of coronally advanced flap for the treatment of single gingival recessions in another long-term 8-year case series study. They reported that an apical shift of the gingival margin occurred in 53% of the cases and that this was associated with a reduction of keratinized tissue; furthermore, the baseline amount of keratinized tissue was indicated as a prognostic factor for recession reduction: the greater the width of keratinized tissue, the greater the reduction of the recession.

The main contraindications for performing the coronally advanced flap as a root coverage procedure are the absence of keratinized tissue apical to the recession defect, the presence of a gingival cleft ('Stillman' cleft) extending into the alveolar mucosa, high frenulum pull at the soft-tissue margin, deep root-structure loss, buccally dislocated root and a very shallow vestibulum depth.

Laterally repositioned (rotational) flap

The laterally repositioned flap is advocated when the local anatomic conditions may render the coronally advanced flap contraindicated. It is not the technique of choice in patients with high esthetic demands (as scar tissue forms in the secondary intention healing at the donor site) but it is well accepted by the patient because it does not involve the withdrawal of tissue from a distant area (the palate) and has an excellent postoperative healing course. In the literature, most reports on the laterally repositioned flap technique are quite dated. Various authors suggested several modifications to the original laterally sliding flap described by Grupe & Warren in 1956 (82) in order to reduce the risk of gingival recession at the donor site: Staffileno (181), proposed the use of a partial-thickness flap, instead of a full-thickness flap, to cover the root exposure. Grupe, in 1966 (81), suggested performing a submarginal incision at the donor site in order to preserve the marginal integrity of the tooth adjacent to the recession defect. Ruben et al., in 1976 (171), introduced a mixed-thickness flap that consisted of a full-thickness flap, performed close to the recession defect for covering the root exposure, and a split-thickness flap created laterally to the full-thickness flap, for covering the bone exposure occurring at the donor site of the full-thickness flap. The most recent publication, before 2004, on the laterally repositioned flap as a root coverage surgical technique, dates back to 1988 (143). The reason for the lack of a more recent interest is related to the low predictability and efficacy of the laterally repositioned flap as a root coverage surgical procedure. In the literature, the reported mean percentage of root coverage ranges between 34% and 82% (31, 33, 65, 84, 109, 142, 171, 199, 215). Complete root coverage data are lacking, with only one study (31, 143) (Table 2) reporting data ranging between 40% and 50%. All techniques reported in the literature consisted of the lateral shift of the pedicle flap only. More recently, Zucchelli et al. (217) suggested a modification of the surgical approach, which added coronal advancement to the lateral movement of the pedicle flap ('laterally moved

Table 2. Mean root coverage and complete root coverage (%) with laterally repositioned flap technique

Study	Flap procedure	Mean root coverage (%)	Complete root coverage (%)
Oles et al. (143)	Laterally repositioned flap	Not available	40.0–50.0
Zucchelli et al. (217)	Laterally repositioned flap	96.0	80.0
Chambrone & Chambrone (44)	Laterally repositioned flap	93.8	62.5

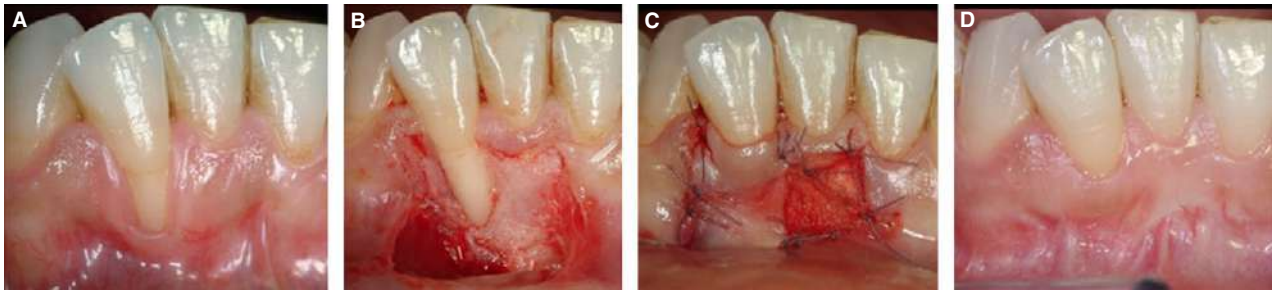

Fig. 14. Laterally moved coronally advanced flap. (A) Baseline gingival recession affecting a buccally dislocated lower lateral incisor. The keratinized tissue mesial to the root exposure was adequate in width and height. (B) Split–full–split flap elevation, de-epithelialization of the receiving bed and root treatment. (C) The flap has been coronally advanced and the keratinized tissue secured to the de-epithelialized anatomic papillae with the sling suture anchored to the lingual cingulum. Equine-derived collagen (gingistat) was sutured to cover the secondary intention wound-healing donor area. (D) At 1 year of follow up. Complete root coverage and increase in keratinized tissue height have been accomplished. Scar tissue formed in the donor site.

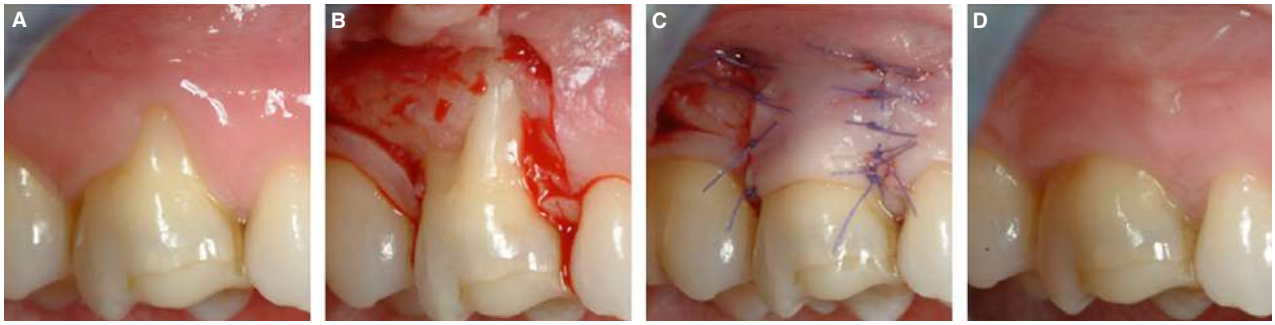

Fig. 15. Laterally moved coronally advanced flap. (A) Baseline gingival recession affecting the mesial root of an upper first molar. The keratinized tissue distal to the root exposure is adequate in width and height. (B) Split–full–split flap elevation and de-epithelization of the receiving bed. Note the depth of the bone dehiscence. Graft techniques would require large withdrawal from the palate. (C) The flap has been coronally advanced and sutured. (D) At 1 year of follow-up. Root coverage and a large increase in keratinized tissue height have been accomplished.

coronally advanced flap') (Figs 14 and 15). In this study, precise measurements of the keratinized tissue lateral to the root exposure were requested: the mesial–distal dimension was 6 mm more than the width of the recession measured at the level of the cemento–enamel junction, whilst the apical–coronal dimension was 3 mm more than the facial probing pocket depth of the adjacent donor tooth. The main surgical modifications (Figs 14 and 15) consisted of the different thickness during flap elevation; split at the level of the surgical papillae, full in that portion of the flap covering the avascular root surface and split again apical to the mucogingival line; the deep and superficial cuts of the muscle insertions to permit coronal advancement of the flap; the de-epithelialization of the anatomical papillae to provide coronal anchorage to the surgical papillae of the flap; and the coronal sling suture anchored to the palatal cingulum of the treated tooth. This technique resulted in a very high mean percentage of root coverage (96%), and complete root coverage was accomplished in the great majority (80%) of patients treated. A recent 24-month study (44) assessed the clinical results obtained with full-thickness laterally positioned flap and citric acid root conditioning for the treatment of localized gingival recession; the mean percentage of root coverage was 94% and complete root coverage was 63%. The laterally moved coronally advanced flap is mainly indicated for the treatment of deep single type gingival recession defects affecting a lower incisor (Fig. 14) or the mesial root of the upper first molar (Fig. 15). In the latter case the presence of very deep bone dehiscence must be expected. Graft techniques would require withdrawal of a very large (in apical–coronal dimension and thickness) amount of tissue from the palate, with an unpleasant postoperative course for patients.

Regenerative procedures

Barrier membranes

Guided tissue regeneration with resorbable and non-resorbable membranes has been used for the treatment of gingival recessions. This procedure has been

shown to offer a predictable modality for root coverage (158, 188, 189), especially in deep recessions, resulting in the regeneration of new connective tissue attachment and bone. The root coverage obtained by polytetraethylene membranes or bioresorbable membranes ranges from 54% to 87% (with a mean of 74%). However, the use of the membrane technique also resulted in several problems such as membrane exposure and contamination, technical difficulties in placing the barrier and possible damage of the newly formed tissue as a result of membrane removal or absorption. Furthermore, recent literature (36, 48, 124) shows that the use of a barrier membrane, in conjunction with a coronally advanced flap, does not improve the result of the coronally advanced flap alone in terms of complete root coverage and recession reduction. At present, the use of a barrier membrane for root coverage procedures appears to be inadvisable, especially considering the high incidence of complications (i.e. membrane exposure) (11, 102, 116, 187, 194).

Enamel matrix derivative

Enamel matrix derivative, in combination with a coronally advanced flap, was introduced to treat gingival recession (135) with the double objective of enhancing root coverage results and inducing periodontal regeneration (59). Recent literature reviews (36, 47, 169) showed that enamel matrix derivative, in conjunction with a coronally advanced flap, improved the percentage of complete root coverage, increased keratinized tissue height and provided better reduction of recession. Histological studies are contradictory, reporting either predominant attachment consisting of collagen fibers running parallel to the root surface without new cementum or Sharpey's fibers (39) and with new bone and new cementum forming only in the most apical portion of root surface, or periodontal regeneration with connective tissue attachment, new bone and new cementum (127, 165). The true clinical rationale to choose this approach with respect to the coronally advanced flap alone or other techniques is unclear; thus, routine use of enamel matrix derivative associated with a coronally advanced flap is not recommended. One may speculate that the application of enamel matrix derivative during mucogingival surgery may be recommended in situations in which a wider extension of new attachment formation between the soft tissue and the root surface could be of clinical relevance. This may be a result of the size of root exposure (a very wide and deep recession defect), or the tooth position (buccally dislocated root) or a concomitant bucco–lingual attachment and bone loss (see histological healing after root coverage surgery). Clinical and histological studies are advocated to confirm such a hypothesis.

Free soft-graft procedures

Epithelialized graft

The free gingival graft is the most widely used surgical technique for increasing the width of attached gingiva. Nevertheless, several authors (20, 23, 151, 166) observed a low degree of predictability of favorable results with this technique in the coverage of exposed root surfaces. In fact, a portion of the graft placed on the denuded root surface does not receive an adequate blood supply, with consequent partial necrosis of the grafted tissue. The literature on free gingival grafts is contradictory and reports percentages of root coverage ranging from 11% to 100% (22, 27, 96, 100, 101, 123–125, 130, 133, 145, 176, 190). This variation may be attributed to differences in the severity of the gingival lesion and in surgical techniques. Nowadays, free autogenous gingival grafts are the last resort when the main goal is root coverage or particularly to meet the esthetic demands of patients. An unfavorable esthetic outcome is related to incomplete root coverage, the white-scar appearance of the grafted tissue that contrasts with the adjacent soft tissues and the malalignment of the mucogingival line. Free gingival grafts can still be used when the main goal of the surgical procedure is to augment keratinized tissue height (especially in mandibular incisors without attached gingiva and with aberrant frenuli), the thickness of gingival tissue and the vestibulum depth. When used for root coverage purposes (Fig. 16), the graft should be sutured coronally to the cemento–enamel junction (to compensate for soft-tissue shrinkage); its thickness should be >1 mm (to increase root coverage predictability) (3, 190); and it should be adapted to the convexity of the crown (to minimize coagulum exposure and destabilization). The free gingival graft is contraindicated in patients with esthetic demands, in deep and wide recession defects and in the presence of deep facial probing pockets associated with gingival recession. Free autogenous gingival grafts can be used as the first surgical procedure in the two-stage technique described by Bernimoulin et al. in 1975 (20). This consists of a first stage of surgery, in which a free gingival graft is performed to increase the keratinized tissue height apical to the gingival recession, and a second stage in which the grafted tissue is coronally advanced to cover the exposed root surface (Fig. 17). A mean per-

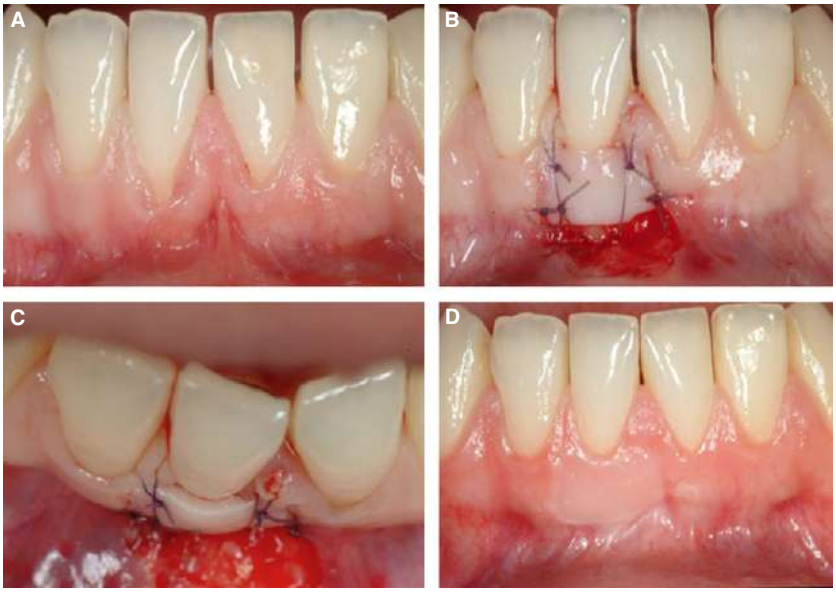

Fig. 16. Free gingival graft for root coverage. (A) Shallow gingival recession affecting a lower incisor with absence of keratinized tissue apical to the exposed root. (B) Suture of the graft. Two coronal interrupted sutures are used to anchor the graft to the base of the papillae. Two apical interrupted sutures stabilize the graft to the periosteum and adjacent soft tissue. A compressive horizontal mattress suture is anchored to the periosteum apical to the graft and suspended around the lingual cingulum. (C) The thickness of the graft must exceed 1 mm. No space should be left between the graft and the convexity of the tooth crown. (D) At 1 year of follow up. Complete root coverage and a significant increase in keratinized tissue height have been accomplished. Note the difference in color between the grafted area and the adjacent soft tissue, and the malalignment of the mucogingival line.

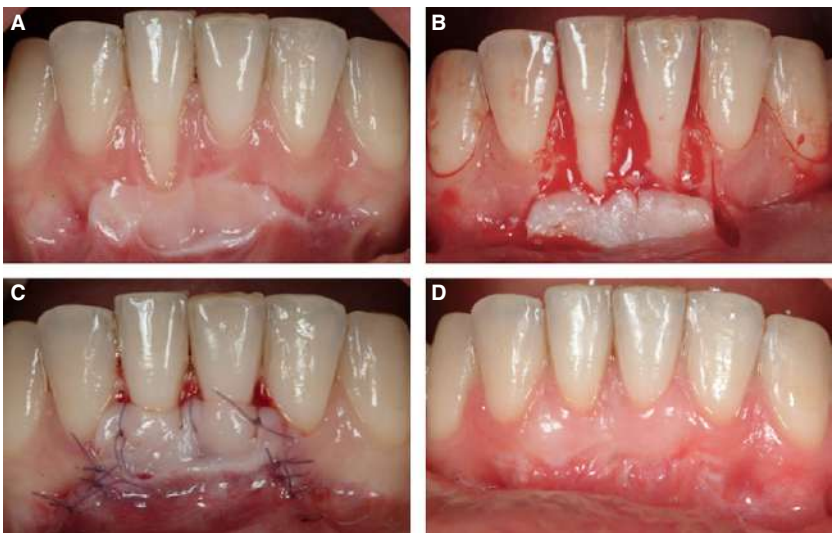

Fig. 17. Two-stage surgical technique for root coverage. (A) A free gingival graft was positioned apical to a deep gingival recession defect affecting a lower central incisor; the image shows the graft after 3 months of healing. Note that the mesial–distal length of the graft has been extended in order to improve the quality/quantity of keratinized tissue of the adjacent central incisor. (B) Second-stage coronally advanced surgery: the grafted tissue has been elevated; only the root of the affected tooth has been mechanically treated and the receiving bed has been deepithelized. (C) The grafted tissue has been coronally advanced and sutured with interrupted sutures along the vertical-releasing incisions and a double sling suture has been anchored to the lingual cinguli of the treated teeth. (D) One year of follow up. Root coverage and an increase in keratinized tissue height have been accomplished in both teeth. Note the difference in color between the grafted area and the adjacent soft tissue.

centage of root coverage ranging from 65% (31, 123) to 72% (155) was reported for the two-stage technique. This procedure is not well accepted by the patient because of the two surgical stages. However, there could be a combination of unfavorable conditions at the tooth with gingival recession that

render this technique as indispensable: the lack of keratinized tissue apical and/or lateral to the root exposure; gingival cleft extending beyond the mucogingival line; and the presence of a shallow vestibulum depth. A recent case report (220) introduced a modified two-stage surgical procedure aiming to improve the esthetic outcome and reduce the patient's morbidity. The main modification of the first stage of surgery consisted of harvesting a free gingival graft of the same height as the keratinized width of the adjacent teeth and suturing it on the periosteum apical to the bone dehiscence. During the second stage of surgery the coronal advancement of the grafted tissue led to root coverage and realignment of the mucogingival line. Zucchelli and De Sanctis (220) showed that by minimizing the apical coronal dimension of the free graft and standardizing the surgical techniques, successful results (in terms of root coverage, increase in keratinized tissue and achieving a color similar to that of the adjacent soft tissues) could be obtained in the treatment of gingival recessions characterized by local conditions, which otherwise preclude, or render unpredictable, the use of one-step root coverage surgical techniques. Randomized controlled studies are advocated to test the efficacy and predictability of the two-stage root coverage surgical technique.

Subepithelial connective tissue graft (bilaminar technique)

The recent literature indicates the bilaminar techniques as the most predictable root coverage surgical procedures (36, 47–49, 51, 141, 169, 205). The biological rationale for these techniques is to provide the graft with an increased blood supply from the covering flap. This will increase the survival of the graft above the avascular root surface (112) and improve the esthetic outcome by hiding, partially or completely, the white-scar appearance of the grated tissue. The mean percentage and the percentage of complete root coverage in the articles of the systematic review of Cairo et al. (36) are summarized in Table 3. During the last two decades clinicians have introduced several modifications to the original bilaminar technique described (163), resulting in more predictable outcomes, in terms of root coverage, and greater esthetic satisfaction for patients. These modifications were related to the type of graft (partially or completely de-epithelialized) harvested from the palate and to the design (envelope type or with a vertical releasing incision) of the covering flap. Some authors used an envelope flap (8, 163) or a repositioned flap (112) to partially cover epithelial connective tissue grafts. Others utilized coronally advanced flaps, with (137, 204) or without (29) vertical releasing incisions, or a laterally moved papillae flap (92) to cover connective tissue grafts. In all surgical approaches reported, the size of the graft exceeded that of the bone dehiscence and it was positioned (and sutured) at the level of, or mainly coronal to, the cemento–enamel junction. Although root coverage became increasingly more predictable, the esthetic appearance of the surgically treated area was often different from that of the adjacent soft tissues. This was caused by the chromatic difference between the uncovered epithelialized portion of the graft and the adjacent soft tissues (8, 112, 163), the dischromy associated with partial exposure of the connective tissue graft as a result of early dehiscence of the covering flap (29, 137, 204), or the difference in thickness between the grafted area and adjacent soft tissues. More recently, in a comparative study by Zucchelli et al. (216), a further modified approach was proposed to improve the esthetic outcome of the bilaminar root coverage procedure (Fig. 18). The main surgical modifications related to the size and positioning of the connective tissue graft: the apico–coronal dimension of the graft was equal to the depth of the bone dehiscence (measured from the cemento–enamel junction to the most apical extension of the buccal bone crest) minus the preoperative height of keratinized tissue apical to the recession defect. The thickness of the graft was <1 mm. The connective tissue graft was positioned apical to the cemento–enamel junction at a distance equal to the height of keratinized tissue originally present apical to the root exposure. This approach was able to improve patient esthetic satisfaction and postoperative course (as a result of the lower dimension of the withdrawal), whereas no difference in terms of root coverage outcomes (mean percentage and percentage of complete root coverage) were reported with respect to a more traditional approach. The successful root coverage outcome of this approach could be explained by the capacity of connective tissue grafts to reduce the apical relapse of the coronally positioned gingival margin during the healing phase of the coronally advanced flap procedure (153). The main indications for the use of a bilaminar root coverage surgical technique are gingival recession in patients with a high esthetic demand in whom the coronally advanced flap is contraindicated as a result of the absence/inadequacy of keratinized tissue apical to the root exposure; gingival recession associated with deep root abrasion, root prominence and root pigmentation (a dark/orange root surface); and gingival recession associated with prosthetic

Table 3. Mean root coverage and complete root coverage (%) with subepithelial connective tissue graft plus coronally advanced flap technique

Study	Flap procedure	Mean root coverage (%)	Complete root coverage (%)
Zucchelli et al. (216)	Subepithelial connective tissue graft plus coronally advanced flap	80.0	97.0
da Silva et al. (54)	Subepithelial connective tissue graft plus coronally advanced flap	75.3	18.1
P. Cortellini (unpublished data)	Subepithelial connective tissue graft plus coronally advanced flap	76.0	Not available
Jepsen et al. (102)	Subepithelial connective tissue graft plus coronally advanced flap	86.9	Not available
Trombelli et al. (194)	Subepithelial connective tissue graft plus coronally advanced flap	81.0	Not available
Borghetti et al. (26)	Subepithelial connective tissue graft plus coronally advanced flap	76.0	28.6
Tatakis & Trombelli (186)	Subepithelial connective tissue graft plus coronally advanced flap	96.0	83.0
Romagna-Genon (170)	Subepithelial connective tissue graft plus coronally advanced flap	84.8	Not available
Wang et al. (201)	Subepithelial connective tissue graft plus coronally advanced flap	84.0	43.7
McGuire & Nunn (128)	Subepithelial connective tissue graft plus coronally advanced flap	93.8	79.0
Aichelmann-Reidy et al. (4)	Subepithelial connective tissue graft plus coronally advanced flap	74.1	Not available
Paolantonio et al. (146)	Subepithelial connective tissue graft plus coronally advanced flap	88.8	46.6
Tal et al. (185)	Subepithelial connective tissue graft plus coronally advanced flap	88.7	42.8
Joly et al. (104)	Subepithelial connective tissue graft plus coronally advanced flap	79.5	Not available
Wilson et al. (210)	Subepithelial connective tissue graft plus coronally advanced flap	64.4	Not available

crowns or implants. Contradictions for the bilaminar techniques are those anatomic situations limiting the possibility to perform pedicle covering flaps (marginal frenuli, high muscle pull, gingival cleft extending in alveolar mucosa and a very shallow vestibulum depth), especially when these unfavorable conditions, in fact, occur more frequently in the lower incisions zone.

Connective tissue graft-harvesting procedures

Different connective tissue graft-harvesting procedures, with the purpose of achieving primary intention palatal wound healing, have been described in the literature: the most common are the trap-door procedures (60) and the envelope techniques with single (99, 118) or double (29) incisions. These procedures have the following common characteristics: a primary split-thickness access flap elevation; the withdrawal of connective tissue graft; and complete closure of the palatal wound with the access flap. The primary objective of these techniques is to reduce patient morbidity by obtaining primary closure of the wound and primary intention healing; however, they need an adequate thickness of the palatal fibromucosa to avoid desquamation of the undermined superficial flap as a result of compromised vascularization (60, 101, 112). The free gingival graft surgical wound heals by secondary intention within 2–4 weeks (67) and has been consistently associated with greater discomfort for the patient as a result of postoperative pain and/or bleeding (58, 67, 101). However, this technique is easy to perform and can be utilized even in the presence of a thin palatal fibromucosa.

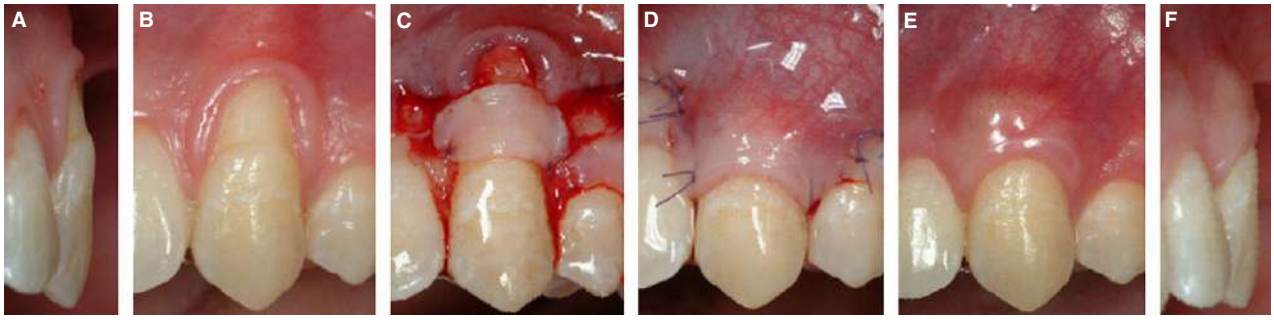

Fig. 18. Bilaminar technique for root coverage. (A) Gingival recession affecting a buccally prominent upper canine (lateral view). (B) A small (<1 mm) height of probable keratinized tissue remained apical to the exposed root. The root prominence and the inadequacy of the remaining keratinized tissue suggest that a connective tissue graft should be added to the coronally advanced flap. (C) The graft covered the bone dehiscence and is sutured slightly apical to the cemento–enamel junction. The papillae coronal to the graft are de-epithelized and provide anchorage to the surgical papillae of the covering flap. (D) The trapezoidal flap is coronally advanced to completely cover the graft. The sling coronal suture was anchored to the palatal cingulum to permit precise adaptation between the keratinized tissue of the flap and the convexity of the tooth crown. (E) One year of follow up. Complete root coverage has been achieved. The keratinized tissue remaining apical to the root exposure characterizes the new soft-tissue margin. There was no sign of graft exposure. (F) The lateral view showed the increase in buccal soft-tissue thickness. A good tooth-emergence profile has been achieved despite the prominence of the root.

The evidence in the literature evaluating differences in patient outcomes and morbidity following use of the connective tissue graft and free gingival graft for root coverage procedures, is minimal. A few prospective comparative studies (58, 80, 207) reported poorer patient outcomes, specifically a greater incidence of postoperative pain, for free gingival grafts compared with connective tissue graft procedures. Recently, a clinical randomized controlled study (223) was performed to compare the postoperative morbidity and root coverage outcomes in patients treated with trap-door connective tissue (control group) and epithelialized (test group) graft-harvesting techniques for the treatment of gingival recession using the bilaminar procedure. In the test group the connective tissue graft was obtained after de-epithelialization of the epithelialized graft with a scalpel blade. No statistically significant differences in painkiller consumption, postoperative discomfort and bleeding (recorded using the visual analog scale) were found between the two groups. By contrast, necrosis of the primary flap in the control patients resulted in a six-fold increase of the intake of anti-inflammatory drugs. The reasons for the lack of differences between the two patient groups are open to speculation; however, a possible explanation may be found in the surgical techniques and, in particular, in the reduced dimensions of the graft or in the protection of the wound area with equine-derived collagen in the test group. At present, study data demonstrate that the height (the apical–coronal dimension) and depth of the harvesting graft, but not the type (primary compared with secondary) of palatal wound healing influence postoperative analgesic consumption. The results of the study also indicate that both types of connective tissue graft can be successfully used under a coronally advanced flap to cover gingival recession, with no statistically significant difference in root coverage outcomes between the grafts. One year post-treatment, 92% of the control gingival defects and 97% of the test gingival recessions were covered with the soft tissue. Furthermore, complete root coverage was achieved in 70% of the controls and in 85% of the test subjects. The only statistically significant difference in the clinical outcomes between the two treatment groups was the greater increase in gingival thickness in the patients treated with the de-epithelialized graft. Any attempt to explain this difference is speculative in nature, but it may be related to the better quality (greater stability and less shrinkage) of the more superficial connective tissue resulting from the de-epithelialization of a free gingival graft with respect to the deeper connective tissue harvested using the trap-door approach (223).

Surgical procedures for multiple recession defects

Gingival recession is rarely localized to a single tooth, and no reports are available on the prevalence of single recession defects compared with multiple recession defects; nevertheless, clinical experience indicates a greater incidence of multiple gingival recessions (219). In the presence of multiple defects, the attempt to reduce the number of surgeries and intraoral surgical sites, together with the need to sat-

isfy the patient's esthetic demands, must always be taken into consideration. Thus, when multiple recessions affect adjacent teeth they should be treated at the same time and, if possible, the removal of soft tissue from distant areas of the mouth (palate) should be minimized to reduce patient discomfort (46).

To date, extensive evidence reports positive outcomes following the use of root coverage procedures in the treatment of localized gingival recessions (36, 48), whilst few studies are currently available reporting the outcomes for the treatment of multiple gingival recessions (46, 154, 218, 222). The coronally advanced flap for multiple recessions was introduced by Zucchelli & De Sanctis (219) as a novel approach to treat more than two adjacent teeth with gingival recession. This technique (Fig. 19) comprises an envelope type of flap (with no vertical releasing incisions); an innovative flap design that anticipates the rotational movement of the surgical papillae during the coronal advancement of the flap; a split (at the level of the surgical papillae) – full (at the soft tissue apical to the root exposure) – split (apical to bone exposure) approach during flap elevation; a double incision (one to dissect muscle insertions from the periosteum and the other to cut muscle from the inner connective tissue lining the mucosa of the flap) to permit coronal advancement of the flap; the de-epithelization of the anatomic papillae; and a various number of sling sutures anchored to the palatal cingulum of the treated teeth. This case series reported 97.1 ± 5.1% mean root coverage and 88.6 ± 20.3% complete root coverage (219). A long-term study (5 years) (218) conducted by the same authors reported stability of the successful outcomes obtained at 1 year of evaluation: 94% of the root surfaces initially exposed by gingival recession were still covered with soft tissue and 85% of the treated recession defects showed complete coverage (218).

A recent systematic review (46) evaluated the results obtained with different root-coverage procedures in the treatment of multiple recession type defects; only four studies were included in this paper: coronally advanced flap (218); coronally advanced flap plus subepithelial connective tissue (42, 45); and subepithelial connective flap with a modified coronally advanced flap (40). A mean percentage of root coverage of 96% was reported, with 73% of complete root coverage. The authors concluded that all the periodontal plastic surgery procedures evaluated (i.e. a coronally advanced flap, either alone or in combination with a subepithelial connective tissue graft) led to improvements in recession depth, clinical attachment level and width of keratinized tissue; further multicenter studies may be required to increase the number of patients and to achieve adequate statistical power.

A recent randomized clinical trial comparing coronally advanced flap, with or without vertical releasing

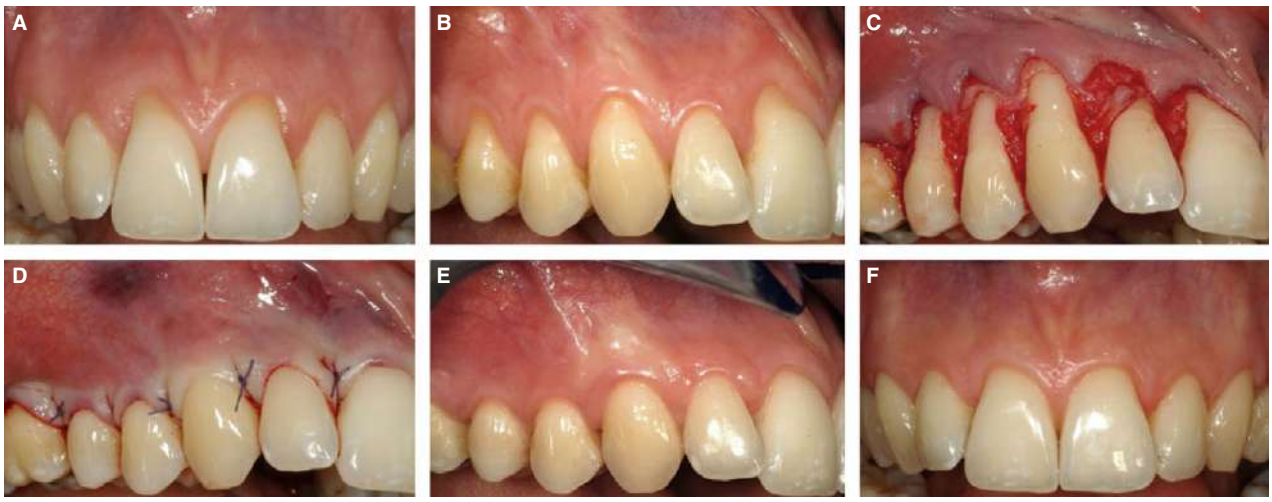

Fig. 19. Coronally advanced flap for multiple gingival recessions. (A) Multiple gingival recessions affecting the anterior teeth in a patient with esthetic demands. Coronally advanced flap surgeries, in the right and left upper sides, were performed. (B) Baseline clinical situation in the first quadrant. (C) An envelope flap from the central incisor to the first molar was elevated using a split–full–split approach. The papillae are de-epithelialized. (D) The flap was anchored coronal to the cemento–enamel junctions of all teeth present in the flap design using sling sutures anchored to the palatal cinguli. (E) One year of follow up. Complete root coverage has been achieved in all treated teeth. An increase in the height of the buccal keratinized tissue can be observed. (F) One year after the same coronally advanced flap treatment of the gingival recessions affecting teeth of the second quadrant. Complete root coverage and good esthetic outcome were achieved in all treated teeth.

incisions, for the treatment of multiple recession, did not report differences in terms of the mean percentage of root coverage between both approaches (222). However, the envelope type of coronally advanced flap was associated with an increased probability of achieving complete root coverage and with a greater increase of buccal keratinized tissue height. Patient satisfaction with esthetics (overall satisfaction, color match and amount of root coverage) was very high for both treatments, with no significant difference observed between them; better results, in terms of postoperative healing and esthetic evaluation, as judged by an independent expert periodontist, were obtained for patients treated with the envelope type of coronally advanced flap. Keloids, which may form along the vertical releasing incisions, were responsible for the worst esthetic evaluation made by the expert periodontist (222).

The coronally advanced flap for multiple gingival recessions should not be considered only as a root coverage surgical procedure but also as a covering flap for connective tissue grafts (subepithelial connective tissue graft) should the keratinized band of tissue apical to the root exposure for root coverage be absent or inadequate (Fig. 20). This inadequacy may be a result of the small height and/or thickness of the keratinized tissue itself or the presence of deep root abrasion (221) or root prominence. Very little data are available on the effectiveness of subepithelial connective tissue grafts in the treatment of multiple recessions (40, 45) and only two long-term studies have been published (155, 225). This trial compared the clinical outcomes of coronally advanced flap alone with those of coronally advanced flap plus connective tissue graft in the treatment of multiple gingival recessions with 5 years of follow-up. Six months after surgery, no statistically significant difference between coronally advanced flaps plus connective tissue grafts and coronally advanced flaps alone was reported in terms of recession reduction and complete root coverage. A different trend was noted over time at the 6-month and 5-year follow-up time points. A slight coronal shift of the gingival margin occurred in the coronally advanced flap plus connective tissue graft, whilst a slight apical shrinkage of the margin was observed in the coronally advanced flap group (154). The progressive coronal improvement of the gingival margin level and the increased percentage of sites with complete root coverage observed at 5 years in the sites treated with coronally advanced flap plus connective tissue graft were explained with the 'creeping attachment' effect over time (124). According to the authors, this effect was facilitated by the thick gingival tissue obtained after healing of the connective tissue graft (154). Conversely, the apical shift of the gingival margin of the coronally advanced flap-treated sites at 5 years was ascribed to the lower thickness/amount of keratinized tissue achieved (36), leading to possible apical relapse of

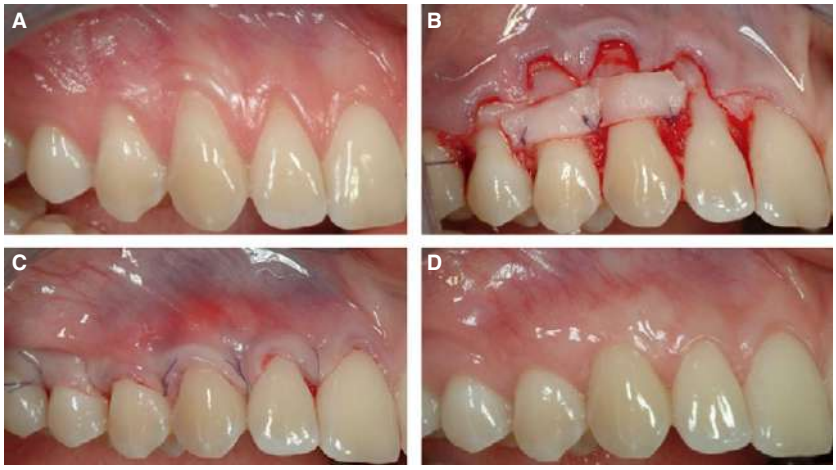

Fig. 20. Coronally advanced flap plus connective tissue graft for multiple gingival recessions. (A) Multiple gingival recessions in a patient with esthetic demands. (B) An envelope flap from the central incisor to the first molar was elevated using a split–full–split approach. A de-epithelized connective tissue graft was sutured at the level of the canine and first premolar, teeth with smaller amounts of residual buccal keratinized tissue. (C) The flap was anchored coronal to the cemento–enamel junctions of all teeth present in the flap design using sling sutures anchored to the palatal cinguli. (D) One year of follow up. Complete root coverage has been achieved in all treated teeth. An increase in the height of the buccal keratinized tissue can be observed in all treated teeth. The increase in soft-tissue thickess was greater for the teeth treated with the adjunct of connective tissue graft. There was no sign of graft exposure.

the gingival margin during the maintenance phase. These data underline, to an even greater extent, the importance of renewing (refreshing) patient motivation for plaque control and an atraumatic toothbrushing technique in the first year(s) postsurgery. Data of the study carried out by Pini Prato et al. (154) could be interpreted as showing that the adjunct use of connective tissue does not really improve the surgical outcomes (until 6 months) compared with the coronally advanced flap procedure alone, but facilitates long-term patient maintenance. A recent randomized controlled trial (225) compared short-term (6 months and 1 year) and long-term (5 years) clinical and esthetic outcomes of the coronally advanced flap, with and without connective tissue grafts, in the treatment of multiple gingival recessions. The authors (225) showed that, in patients with high standards of oral hygiene and undergoing a very strict regimen of postsurgical control visits, both techniques were effective in reducing recession depth and achieving complete root coverage at 6 months and 1 year, with no statistically significant differences between these time points. Better results, in terms of postoperative course and color-match evaluation made by an independent expert periodontist, were obtained in patients treated with the coronally advanced flap procedure. Conversely, the coronally advanced flap plus connective tissue graft procedure was associated with an increased probability of obtaining complete root coverage at 5 years. Further investigations are advocated.

Tunnel technique

The tunnel procedure for root coverage was introduced in 1994 and termed the supraperiosteal envelope technique (8, 9). The unique characteristic of this procedure is that the interdental papillae are left intact. A connective tissue graft is placed in the tunnel and it does not need to be completely covered as long as the dimension of the graft is sufficient to ensure graft survival. An advantage of not covering the graft completely is that additional keratinized tissue is gained, whereas a disadvantage is that the exposed tissue might not be an exact color match. Conversely, the absence of vertical incisions has a tendency to produce better esthetics. Probably the main advantage of the technique is the minimally invasive nature of the surgery, which results in negligible postoperative discomfort at the recipient site. Recently, the tunnel technique was modified to include coronal positioning of the marginal tissue, which allows complete coverage of the graft (E. P. Allen, Center for Advanced Dental Education, Dallas, Texas; course manual) (Fig. 21). This was accomplished by dissecting more deeply to free up the facial tissue and by lifting the papillae off the interproximal septum from the facial and lingual aspects. These two features allow greater coronal mobilization of the tissue margin. Successful execution of the technique requires almost a microsurgical approach, using smaller, specially designed instruments, small sutures and a unique suturing technique. Aroca et al. (14) tested, in a controlled randomized split-mouth study, the effi-

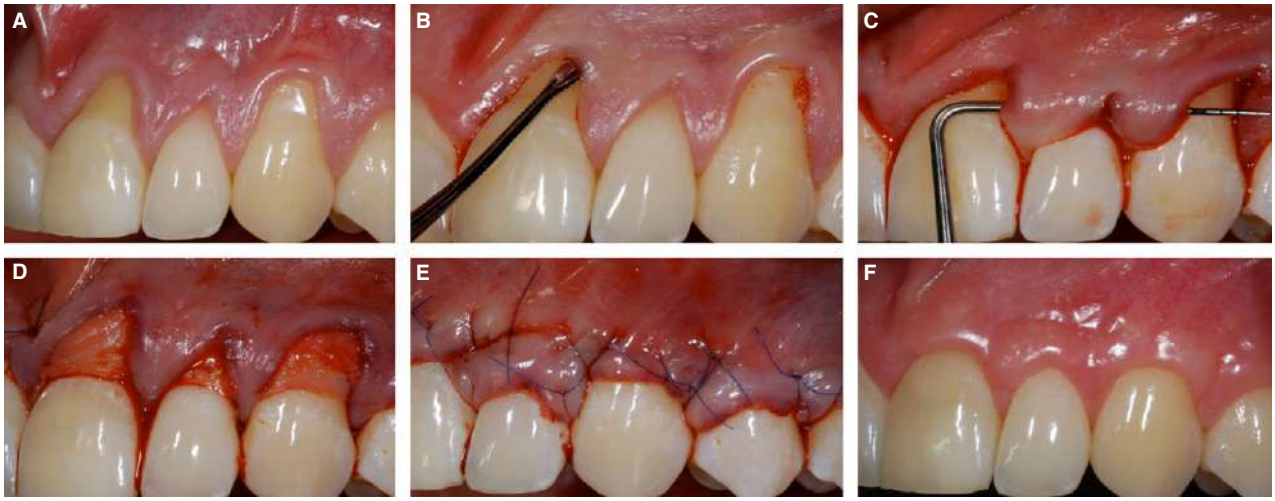

Fig. 21. (A) Baseline. Multiple Miller Class 1 recessions. (B) Use of the tunnel instrument to completely mobilize the flap. (C) The flap was completely mobilized. Note that a tension-free flap was obtained. (D) The palatal connective tissue graft was placed in the tunnel and fixed with mattress and sling sutures. (E) The tunnel was sutured coronally to the cemento–enamel junction in such a way that the connective tissue graft and the recession defects were completely covered. (F) At 12 months following surgery, complete coverage of the recessions was achieved. Courtesy of Anton Sculean (University of Bern).

cacy of a modified tunnel plus connective tissue graft technique in the treatment of multiple Class III gingival recessions. The data showed predictable results at 1 year (14). Recently, the same author (15), in a split-mouth randomized controlled trial, showed the findings of treatment of Miller Class I and II multiple adjacent gingival recessions with a modified coronally advanced tunnel technique in conjunction with a connective tissue graft. At 12 months this technique resulted in statistically significant improvements in complete root coverage (85%), mean root coverage (90 ± 18%) and mean keratinized tissue width (2.7 ± 0.8 mm) compared with baseline ($P < 0.05$). The favorable root coverage results of the tunnel procedure and its modification are summarized in Table 4.

Allograft

The subepithelial connective tissue graft is a predictable and versatile technique in which a bilaminar vascular environment is created to nourish the graft. However, harvesting the palatal area increases postoperative morbidity and is time consuming (104). The need for a second surgical procedure to harvest donor tissue is a disadvantage of the connective tissue graft procedure because only a limited amount of donor tissue is available for multiple recession defects. Thus, there has been a desire to find a substitute for the autogenous donor tissue (19). As a response, acellular dermal matrix graft has been used as a substitute for connective tissue grafts in root coverage procedures (Fig. 22). The acellular dermal matrix graft is a dermal allograft processed to extract cell components and the epidermis, whilst maintaining the collagenous scaffolding (43). The remaining dermal layer is washed in detergent solutions to inactivate viruses and to reduce rejection and then is cryoprotected and rapidly freeze dried in a proprietary process to preserve its biochemical and structural integrity. The allograft acts as a scaffold for the vascular endothelial cells and fibroblasts to repopulate the connective tissue matrix and encourage the epithelial cells to migrate from the adjacent tissue margins (211). The healing process observed in the allograft is similar to that seen in autogenous grafts (178, 183, 184). Similar root coverage outcomes have been reported in several studies (4, 36, 48, 52, 56, 70, 95, 104, 139, 141, 146, 212) that compared coronally advanced flaps plus acellular dermal matrix grafts with coronally advanced flaps plus connective tissue grafts.

Recent systematic reviews (36, 48) did not show a statistically significant difference between the coronally advanced flap plus the acellular dermal matrix graft compared with the coronally advanced flap alone in terms of complete root coverage, recession reduction and keratinized tissue gain, suggesting no additional benefit with the use of the acellular dermal matrix graft. Surprisingly, even the comparison between coronally advanced flap plus acellular dermal matrix graft and coronally advanced flap plus connective tissue graft showed no statistically significant differences for complete root coverage and recession reduction, even though a tendency favoring connective tissue grafts was observed for both variables. A statistically significant difference in gain of keratinized tissue was detected with use of the connective tissue graft. Furthermore, a meta-analyses of two studies (52, 212) showed large heterogeneity in recession reduction for both comparisons

Table 4. Mean root coverage and complete root coverage (%) with subepithelial connective tissue graft plus tunnel technique

Study	Flap procedure	Mean percentage root coverage	Mean percentage complete root coverage
Allen (8)	Subepithelial connective tissue graft plus tunnel technique	84.0	Not available
Zabalegui et al. (213)	Subepithelial connective tissue graft plus tunnel technique	91.6	66.7
Tozum & Dini (191)	Subepithelial connective tissue graft plus tunnel technique	95.0	Not available
Tozum et al. (192)	Subepithelial connective tissue graft plus tunnel technique	96.0	Not available
Georges et al. (73)	Subepithelial connective tissue graft plus tunnel technique	85.0	Not available
Aroca et al. (15)	Connective tissue graft plus modified coronally advanced tunnel technique	90.0	85

Fig. 22. Coronally advanced flap for multiple gingival recessions plus collagen matrix. (A) Multiple gingival recessions affecting lower teeth. (B) Lateral view of the lower incisor and canine, showing minimal height of keratinized tissue and gingival thickness. (C) An envelope flap from the central incisor to the second premolar was elevated using a split–full–split approach. Collagen matrix was applied site-specifically at the level of the lateral incisor and canine and sutured at the base of the de-epithelialized papillae. (D) The flap was anchored coronal to the cemento–enamel junctions of all teeth present in the flap design using sling sutures anchored to the lingual cinguli. (E) One year of follow up. Lateral view of the lower incisor and canine showing an increase in gingival height and thickness. (F) One year of follow up. Complete root coverage has been achieved in all treated teeth.

(coronally advanced flap plus acellular dermal matrix graft vs. coronally advanced flap alone), thus indicating the possible influence of patient-related factors, operator skill and severity of recession on the clinical outcomes. However, the coronally advanced flap plus acellular dermal matrix graft gave better overall esthetic outcomes, as reported by both clinicians and patients, when compared blind with the coronally advanced flap plus connective tissue graft, even though it showed less complete root coverage (4). This finding may be related to different color matches with adjacent tissues for the acellular dermal matrix graft and connective tissue graft, or poorer healing for the connective tissue graft, in which size exceeds the bone dehiscence (216). The data from the literature on the use of acellular dermal matrix grafts for root coverage is not conclusive and its use may be associated with ethical concerns and risk of disease transmission.

Recently, a new collagen matrix of porcine origin (Mucografts Prototype) has been developed. Its intended mechanism of action is through acting as a three-dimensional scaffold that allows the ingrowth and repopulation of fibroblasts, blood vessels and epithelium from surrounding tissues, eventually being transformed into keratinized tissue. Only one clinical trial investigating the use of collagen matrix is available in the literature (174); in this trial, the authors tested the efficacy of Mucograft to build up a clinically sufficient width of newly formed keratinized tissue and assessed the esthetic outcomes and postoperative morbidity in comparison with the connective tissue grafts technique. The collagen matrix, when used as a soft-tissue substitute aiming to increase the width of keratinized tissue or mucosa, appears to be as effective and predictable as the connective tissue graft.

McGuire & Scheyer (129) proposed a study to test whether the xenogeneic collagen matrix could be useful for covering recession defects compared with the gold-standard coronally advanced flap plus connective tissue graft. The single-masked, randomized-controlled split-mouth trial showed an average of 84% root coverage at 6 months and 89% at 1 year with collagen matrix plus coronally advanced flap; better results were achieved with coronally advanced flap plus connective tissue graft: 97% of root coverage at 6 months and 99% at 1 year. The authors underlined

that the measures, evaluated statistically, were different but balanced with subject-reported outcomes (subjects' assessments of pain/discomfort and esthetics), and that collagen matrix plus coronally advanced flap presented an intriguing comparison with the traditional connective tissue graft gold standard. A recent randomized controlled trial (38) evaluated the use of a porcine collagen matrix plus coronally advanced flap as an alternative to coronally advanced flap plus connective tissue graft for the treatment of gingival recessions. At 12 months, porcine collagen matrix plus coronally advanced flap resulted in a mean root coverage of 94% compared with a mean root coverage of 97% for coronally advanced flap plus connective tissue graft. From a statistical point of view, these measures are different but, according to the authors, the outcomes achieved by the porcine collagen matrix plus coronally advanced flap procedure were clinically comparable with those of the coronally advanced flap plus connective tissue graft group and similar to those expected from the coronally advanced flap plus connective tissue graft, as stated in previous literature reviews. A recent single-blinded, randomized, controlled, split-mouth multicenter trial (103) evaluated the clinical outcomes of the use of a xenogeneic collagen matrix (test group) plus the coronally advanced flap or coronally advanced flap alone in the treatment of localized recession defects. At 6 months, root coverage (primary outcome) was 76% for test defects and 73% for control defects ($P = 0.169$), with 36% of test defects and 31% of control defects exhibiting complete root coverage. The increase in the mean width of keratinized tissue was higher in test defects (from 1.97 to 2.90 mm) than in control defects (from 2.00 to 2.57 mm) ($P = 0.036$). Likewise, test sites had more gain in gingival thickness (0.59 mm) than did control sites (0.34 mm) ($P = 0.003$). Larger (≥3 mm) recessions ($n = 35$ patients) treated with collagen matrix showed higher root coverage (72% vs. 66%, $P = 0.043$), as well as more gain in keratinized tissue and gingival thickness. The authors (103) concluded that coronally advanced flap plus collagen matrix was not superior with regard to root coverage, but enhanced gingival thickness and width of keratinized tissue when compared with coronally advanced flap alone. For the coverage of larger defects, coronally advanced flap plus collagen matrix was more effective.

Root conditioning

Chemical root-surface conditioning using a variety of agents has been introduced in order to detoxify, decontaminate and demineralize the root surface, thereby removing the smear layer and exposing the collagenous matrix of dentin and cementum (88–91). Various acids have been used for chemical root-surface conditioning, including citric and phosphoric acids (167), ethylenediaminetetraacetic acid (113) and tetracycline hydrochloride (110). In an animal model, these procedures are believed to be able to induce cementogenesis and enhance attachment by connective tissue ingrowth and/or demineralization (71, 209). However, in human studies, no clinical advantages were observed (61, 120). The clinical relevance of root conditioning with an acid agent in routine periodontal surgery is still uncertain and there is no evidence that these products will improve root coverage (36, 48).

Healing after root coverage procedures

The major goal of periodontal plastic surgery is the coverage of roots exposed by gingival recession (203). These days, the covering of denuded roots is a predictable and effective procedure, usually with highly esthetic results. However, the nature of the attachment between the grafted tissue and the root surface is not well understood. A potential weakness of the technique is that a pocket may be created where the recession has been covered (86) A true new connective tissue attachment would be preferable to a long junctional epithelium (86). The aim of the present section is to summarize current knowledge about the regenerative events following the surgical treatment of recession defects. Specifically, the character of histological healing involved will be discussed. Histological evaluation of the nature of the interface between the newly covered root surface and overlying gingival tissues is based on animal studies and isolated case reports.

Animal studies

Animal studies in dogs and monkeys were undertaken as long ago as 1950, using different periodontal plastic surgery procedures: lateral (32, 208) and coronal (77) displaced flaps, coronal flap associated with membranes (76) and connective tissue grafts were performed to achieve root coverage in experimental gingival recession. Similar histological and histomorphometrical findings were reported: connective tissue attachment (fibers functionally inserted or parallel to the root) with new bone and cementum was found in

about 50% of the most apical portion of the root; and long junctional epithelium was observed in the other 50% of the most coronal root surface. Better results were reported following guided tissue-regeneration procedures (76), with an average of 73% of new-attachment formation. As the periodontal ligament is the source of granulation tissue capable of being transformed into connective tissue attachment, it is plausible that the topographic distribution along the root exposure between connective tissue attachment and long junctional epithelium is concentric. The connective tissue attachment should be more peripheral and close to the periodontal ligament and the long junctional epithelium located in the center of the lesion. This may explain why narrow defects may heal with a complete new-attachment formation, whereas, in wider defects, the same area of the new attachment fails to cover the central portion of the defect (77). A recent randomized controlled study (197) in minipigs evaluated the histological and clinical outcomes of the use of a xenogeneic collagen matrix in combination with a coronally advanced flap in the treatment of localized Miller Class I gingival recessions. The authors showed that the matrix was completely incorporated into the adjacent host connective tissues in the absence of a significant inflammatory response. The healing was characterized by the formation of new cementum and new connective tissue attachment in the apical aspect of the defect and by a junctional epithelium in its most coronal third. When compared with the coronally advanced flap alone, both techniques rendered similar clinical outcomes, although the collagen matrix graft attained more tissue regeneration, with a shorter epithelium and a larger new-cementum formation (197).

Human studies

A number of human histological studies (30, 75, 93, 94, 122, 127, 149) (Table 5) have been performed on the use of autogenous free tissue grafts or connective tissue grafts with pedicle flaps as root coverage procedures. A combination of long junctional epithelium and connective tissue attachment was demonstrated; the deeper the recession and the greater the patient's compliance, the larger the amount of new connective tissue attachment with newly formed cementum and bone that was generated. Other studies (50, 148, 198) (Table 6) investigated the histological assessment of new attachment following treatment of human buccal recession with a guided tissue-regeneration procedure. Higher amounts of periodontal regeneration and a satisfactory percentage of root coverage were reported.

Three studies used a combination of conventional mucogingival surgery (connective tissue graft and coronally advanced flap procedures) and enamel matrix protein derivative to treat a buccal gingival recession (39, 127, 165) (Table 7). Contradictory histological outcomes were reported. The study, by Carnio et al. (39), reported a predominant attachment consisting of collagen fibers running parallel to the root surface without new cementum or Sharpey's fiber formation. New bone and new cementum were found only in the most apical portion of the root surface. By contrast, Rasperini et al. (165) and McGuire's and Cochran (127) studies showed periodontal regeneration with connective tissue attachment and new-bone and new-cementum formation.

A human histological case series (53) comparing connective tissue grafts and acellular dermal matrix grafts after 6 months of healing indicated comparable gingival attachment to the root surface (a combination of long junctional epithelium and connective tissue adhesion). The acellular dermal matrix graft seemed well incorporated with new fibroblasts, vascular elements and collagen, whilst retaining its elastic fibers throughout.

The findings of the literature are not conclusive and are sometimes controversial; very few studies, mainly case reports, are available. However, within the limits of the reported studies, it is possible to affirm that the combination of a long junctional epithelium and connective tissue attachment is created when gingival recessions are treated with periodontal plastic surgical procedures. The concentric distribution between connective tissue attachment and long junctional epithelium suggests that regenerative procedures (guided tissue regeneration or enamel matrix derivate) could be appropriate, preferably in wide defects or in the case of a buccally dislocated root with larger root exposure with respect to bone position. The variability of the results in the reported studies indicates that further histological investigations are needed.

Conclusions

The present article reviews the most recent knowledge in terms of the etiology, diagnosis, classification, prognosis and surgical treatment of gingival recessions. The etiology of gingival recession is well defined: toothbrushing trauma and bacterial plaque

Table 5. Characteristics of human histological studies: connective tissue graft or subepithelial or connective tissue graft

Baseline							Postoperative						
Study	**No. of teeth**	**Gingival recession (mm)**	**Periodontal pocket depth (mm)**	**Keratinized tissue (mm)**	**Notches**	**Surgical technique**	**Gingival recession (mm)**	**Periodontal pocket depth (mm)**	**Keratinized tissue (mm)**	**Connective tissue (mm)**	**Long junctional epitheliummm)**	**New bone (mm)**	**New cementum (mm)**
Pasquinelli (149)	1	6.0	2.0	0.0	No	Connective tissue graft	5.0	1.0	5.0	4.4	2.6	4.0	No
Harris (93)	2	2.0	2.0	0.0	Yes	Subepithelial connective tissue graft	0.0	0.5	5.0	No	Yes	No	No
		3.0	2.0	1.0	Yes		0.5	0.5	3.0	Yes	Yes	No	No
Harris (94)	1	4.0	1.0	2.0	No	Subepithelial connective tissue graft	0.0	1.0	4.0	Yes	No	Yes	No
Bruno & Bowers (30)	1	8.0	2.0	10	No	Subepithelial connective tissue graft	1.0	1.0	4.0	3.0–5.0	No	Yes	Yes
Goldstein et al. (75)	1	5.0	1.0	3.0	No	Subepithelial connective tissue graft	1.0	1.0	5.0	0.7	No	Yes	Yes
Majzoub et al.(122)	2	3.0	1.0	0.5	No	Subepithelial connective tissue graft	0.5	1.0	3.0	Yes	3.8	Yes	Yes
		2.5	1.0	1.5			0.0	1.0	5.0	Yes	3.4	Yes	Yes
McGuire & Cochran (127)	2	4.24	1.80	Not available	Yes	Subepithelial connective tissue graft	0.29	0.5	Not available	No	Yes	No	Yes

Table 6. Characteristics of human histological studies: guided tissue regeneration

Baseline							Postoperative						
Study	**No. of teeth**	**Gingival recession (mm)**	**Periodontal pocket depth (mm)**	**Keratinized tissue (mm)**	**Notches**	**Surgical technique**	**Gingival recession (mm)**	**Periodontal pocket depth (mm)**	**Keratinized tissue (mm)**	**Connective tissue (mm)**	**Long junctional epithelium (mm)**	**New bone (mm)**	**New cementum (mm)**
Cortellini et al. (50)	1	8.0	1.0	0.0	Yes	Guided tissue regeneration	4.0	1.0	3.0	3.6	No	1.84	2.48
Vincenzi et al. (198)	1	Not available	Not available	Not available	Yes	Guided tissue regeneration	2.0	2.0	Not available	2.3	No	Yes	Yes
Parma-Benfenati & Tinti (148)	1	7.0	4.0	0.0	Yes	Guided tissue regeneration	4.0	1.0	1.0	5.6	No	6.7	5.6

Table 7. Characteristics of human histological studies: subepithelial connective tissue graft plus enamel matrix derivate

Baseline							Postoperative						
Study	**No. of teeth**	**Gingival recession (mm)**	**Periodontal pocket depth (mm)**	**Keratinized tissue (mm)**	**Notches**	**Surgical technique**	**Gingival recession (mm)**	**Periodontal pocket depth (mm)**	**Keratinized tissue (mm)**	**Connective tissue (mm)**	**Long junctional epithelium (mm)**	**New bone (mm)**	**New cementum (mm)**
Rasperini et al. (165)	1	6.0	1.0	0.0	Yes	Subepithelial connective tissue graft plus enamel matrix derivate	4.0	1.0	3.0	2.2	No	1.80	Yes
Carnio et al. (39)	4	4.0	5.0	0.0		Subepithelial connective tissue graft plus enamel matrix derivate	0.0	1.0	4.0			Yes	Yes
		5.0	2.0	0.0	Yes		1.0	2.0	4.0	Yes	No	No	No
		6.0	2.0	0.0			2.0	2.0	5.0			No	No
		6.0	1.0	1.0			3.0	1.0	4.0			No	No
McGuire & Cochran (127)	2	4.25 (mean)	1.80 (mean)	Not available	Yes	Coronally advanced flap plus enamel matrix derivate	0.29 (mean)	0.5	Not available	Yes	Yes	Yes	Yes

are the most frequent causative factors for gingival recessions acting on an existing lack of alveolar buccal bone that may be anatomical or acquired. Conversely, diagnosis, prognosis and, especially, classification of gingival recession will need to be revisited on the basis of the recent findings. Major difficulties arise when the main reference parameter for diagnosing, measuring and evaluating the treatment outcome of gingival recession is lack of the cemento–enamel junction. This occurs quite frequently when toothbrushing trauma also creates noncarious cervical lesions, together with gingival recession. A criticism of Miller's classification and the prognosis of gingival recessions relates to the unclear procedures used to ascertain the amount of soft/hard tissue loss in the interdental area to differentiate Class III and IV and the unclear influence of tooth malpositioning. Until new knowledge better defines these aspects, the use of clinical methods to predetermine the level of root coverage is recommended, at least to improve the patient's perception of their esthetic outcome. Surgical coverage of gingival recession is very predictable, at least for a single type of defect. The gold standard is the bilaminar technique, which mainly consists of a coronally advanced flap covering a connective tissue graft because the adjunctive use of connective tissue grafts increases the likelihood of achieving complete root coverage, with respect to use of the coronally advanced flap alone, especially in long-term follow-up. Although because of the limited dimension in single type recession defects the adjunctive use of connective tissue grafts is quite often indicated to improve complete root coverage predictability, the same cannot be assumed for multiple gingival recessions. This is because of the limited amount of tissue that can be harvested from the palate, the increased patient morbidity and the enhanced possibility of dehiscence in the covering flap as a result of increasing the dimension of the connective tissue grafts. This last factor is particularly unacceptable in patients with esthetic demands as a result of the difference in color, texture and surface characteristic of the exposed grafted area with respect to the adjacent soft tissue. Studies are needed to clarify, in greater detail, which, and how many, gingival recessions should be treated with the adjunctive use of connective tissue grafts when treating multiple gingival recessions. In this view, the utilization of substitutes for the connective tissue grafts would be strongly encouraged. Unfortunately, despite recent improvements, none of the available allograft materials can be considered as a true substitute for connective tissue grafts.

One of the most important innovations in gingival recession treatment, which has already started but needs future development and improvement, is the design of clinical trials with the patient's outcome, esthetics and morbidity in particular, as primary outcome measures. This is likely to change current success evaluation criteria and perhaps also the decisional matrix in the surgical management of gingival recession.

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