

Coronally advanced flap and combination therapy for root coverage. Clinical strategies based on scientific evidence and clinical experience

PIERPAOLO CORTELLINI & GIOVANPAOLO PINI PRATO

Gingival recession is defined as the displacement of the soft tissue margin apical to the cemento–enamel junction (5) and is a frequent clinical feature in populations with both good (69, 113) and poor (9, 69, 131) standards of oral hygiene. Localized loss of attachment with gingival recession is located mainly at the interdental spaces in patients with plaque-induced periodontal inflammation and at the buccal surfaces of teeth in patients with high standards of oral hygiene (69, 113) and may affect single or multiple root surfaces. It has historically been associated with mechanical factors such as traumatic toothbrushing impacting on predisposed thin soft tissues (108), even though a recent systematic review (99) concluded that data to support or refute the association between toothbrushing and gingival recession are still inconclusive. This is a severe ‘black hole’ in our knowledge, because knowing the cause of recession would greatly help in the planning of an appropriate clinical approach directed to improve the prognosis of this type of periodontal lesion. In fact, prognosis is defined as ‘prediction of the future course of a disease in terms of disease outcomes following its onset and/or treatment’ and might be positively modified if the causative agents are controlled; in other words, if periodontitis is properly treated and if the traumatic toothbrushing technique is corrected.

A long-standing debate in the scientific community relates to whether it is possible to halt the progression of gingival recession defects by modifying the

oral hygiene habits of patients and/or by applying mucogingival surgical procedures (6). A long-term clinical study recently reported that shallow recessions showed a tendency for further apical displacement of the gingival margin in highly motivated patients with high standards of oral hygiene and enrolled in a stringent supportive periodontal care system (4–6 months) over a period ranging from 10 to 27 years (1). In the same population of patients, contralateral grafted sites showed stability or even a coronal shift of the gingival margin over the same time frame. The study concluded that untreated gingival recessions show a negative prognosis over time in spite of good patient motivation, while the prognosis is improved after applying mucogingival procedures. Gingival recession remains a highly prevalent problem (57, 105) and potentially impacts on both esthetics and dentine hypersensitivity. Patients therefore commonly ask about treatment options for both single and multiple buccal recession defects.

The ultimate goal of root-coverage procedures is the complete resolution of the recession defect, with minimal probing depths after treatment, along with a nice chromatic and texture integration of the covering tissues with the adjacent resident soft tissues (20, 21, 31, 78, 102). Clinicians are challenged to achieve outcomes that meet these exacting standards, and therefore need a sound, clinically oriented and scientifically supported decision-making process to plan the therapeutic approach, to predict the outcome and, finally, to achieve it.

During the last three decades, several surgical techniques have been proposed to treat single and multiple gingival recessions. In the 1970s and 1980s, the main treatment goals were achieving recession reduction and increasing keratinized tissue. The proposed surgical techniques were pedicle flaps (laterally or coronally positioned) and free gingival grafts. During the 1980s and 1990s, new approaches, such as bilaminar techniques or regenerative procedures, were proposed to achieve the goal of complete root coverage. In the last decade, because of the ever-increasing esthetic demands from patients, surgical techniques have been further developed to obtain complete root coverage associated with a perfect integration of the grafted tissue with the adjacent soft tissues (20, 31).

In broad terms, three different approaches can be identified from the published literature: (i) the free gingival graft (117), (ii) the coronally advanced flap (3), and (iii) combined procedures, based on a coronally advanced flap with tissue/material interposed between the flap and the root surface. The most common of the latter approaches are based on a coronally advanced flap plus a connective tissue graft (coronally advanced flap + connective tissue graft) (63), a nonresorbable barrier (91), a bio-resorbable barrier (92, 101), enamel matrix derivative (25, 41, 89, 100, 115), platelet-rich gel (62), acellular dermal matrix (51), or living tissue-engineered human fibroblast-derived dermal substitute (129).

Although all the proposed techniques have shown potential for root coverage, meta-analyses from several systematic reviews (20, 29, 31, 85, 102) showed the greatest potential for recession reduction and complete root coverage when applying coronally advanced flap or combined procedures. These are therefore the approaches of choice to date.

The aim of this review was to provide a critical analysis of clinical studies and controlled clinical trials performed either with coronally advanced flap therapy alone or with coronally advanced flap therapy in combination with tissues/materials, and to propose sound, clinically oriented and scientifically supported flow charts to help clinicians in their decision-making processes for the treatment of localized and multiple gingival recessions.

Overview

From a methodological point of view, this review will consider published evidence on coronally advanced flap therapy, alone, or in combination with tis-

sues/materials, from a clinical perspective with the aim of helping clinicians in their decision-making process. The review will include: (i) analysis of the potential prognostic factors (patient, tooth/site and technique-related factors), (ii) discussion of the surgical procedures, (iii) comparison of different coronally advanced flap-based approaches, (iv) evaluation of the healing dynamics and long-term stability of outcomes, and (v) a discussion of the patient-related outcomes and side effects of therapy. The review will end with referenced flow charts.

Single or multiple gingival recessions and patients' requests for root coverage challenge the clinician's ability to choose the best approach and to predict the outcome. Ideally, a clinician should first discuss with the patient the desired/expected outcome(s), then select the best option to reach those outcome(s).

Interestingly, very few studies have considered 'patient satisfaction' and this should be the true outcome of a procedure that mainly addresses the goal of esthetic improvement. A study was performed to investigate the perceived esthetic outcomes of simulated root-coverage procedures using three different groups of 'evaluators': patients, dentists and periodontists (104). Complete root coverage was perceived as the most desirable outcome by the three groups.

Similarly, information about changes in dentinal hypersensitivity, another important outcome for patients, is seldom reported. A recent multicenter randomized clinical study reported that coronally advanced flap therapy alone and coronally advanced flap therapy associated with a connective tissue graft were both effective in reducing dental hypersensitivity (37).

Most studies have reported surrogate outcomes, such as complete root coverage, amount of root coverage, per cent root coverage and changes in the amount of keratinized tissue. Therefore, this review will focus on patient outcomes when available, but will mainly use surrogate outcomes to draw conclusions.

An additional problem has to be highlighted and should be taken into account when comparing results from different studies: understanding how 'complete root coverage' or 'per cent root coverage' are defined by different authors. The issue is especially relevant when teeth with large abrasion cavities and/or deep steps involving the cemento-enamel junction are included (Fig. 1A–C). In these instances, the cemento-enamel junction is no longer detectable and the record of root coverage becomes a guess. There is, in fact, a tendency to declare a root to be 'completely



Fig. 1. Coronally advanced flap on multiple gingival recessions associated with root abrasions. (A) Severe multiple gingival recessions on the maxillary right quadrant, associated with severe steps and abraded cemento–enamel junction. The residual gingiva is thick and wide.

(B) An envelope flap has been coronally advanced to cover a connective tissue graft, positioned on the abraded root surfaces. (C) The 1-year clinical outcome. Note that the abraded cemento–enamel junction is visible making evaluation of the outcome difficult.

covered' when the gingival margin reaches a position that the clinician 'feels' is the maximum possible coverage obtainable in that specific case. This might in reality reflect the true maximum potential outcome, but it still is not an 'objective' measure.

Potential prognostic factors

Prognostic factors are defined as the characteristics of a particular patient that can be used to predict, with greater accuracy, the patient's eventual outcome. Prognostic factors do not predict the outcome completely, but do influence the outcome of treatment (64). Potential prognostic factors for root coverage can be divided into three different categories: patient-related factors, tooth/site-related factors and technique-related factors.

Patient-related factors

Few articles in the periodontal literature are available that debate the possible influences of age, gender, race and systemic disease on the outcomes of root coverage procedures. There is weak evidence that poor oral hygiene will negatively influence the success of root coverage (19). Similarly, there is little information on the influence of traumatic toothbrushing in the recurrence of recession after treatment (127). Smoking is a controversial issue. Some papers report less favorable outcomes in terms of root coverage in smokers (78, 81, 114, 124, 133), whereas other studies do not find differences between smokers and nonsmokers (4, 16, 50, 54, 73, 120). A recent systematic review (28) concluded that smoking may negatively influence gingival recession reduction and clinical attachment gain, and smokers may exhibit fewer sites with complete root coverage. In reality, most of the studies cited in the review by Chambrone et al. (28) were not designed to test the influence of smoking on

root coverage and do not provide a comparison between smokers and nonsmokers.

Tooth/site-related factors

Interestingly, many of the tooth/site-specific factors that are believed to be, and are frequently cited as, relevant prognostic factors, have never been tested in sound clinical studies. For example, there is no information as to whether tooth position (buccal or lingual), tooth vitality and depth of the vestibule might influence the outcome of mucogingival procedures. Limited, and often conflicting, information is available on the results of root coverage procedures performed on different tooth types or on maxillary or mandibular teeth (14, 73, 81, 82).

Cervical dental caries and/or abrasions are often associated with gingival recessions. Various approaches have been attempted to treat gingival recession associated with cervical lesions, and excellent clinical results have been achieved, both in terms of root coverage and cosmetic outcomes (42, 44, 72, 76, 90), showing that superficial caries lesions or abrasion defects do not seem to impair the possibility to cover a root.

Root curvature might potentially influence the outcome of root coverage. This hypothesis is based on the size of the avascular area, which is larger in prominent root surfaces. A study (107), performed to compare the root curvature of four different dental morphotypes (central incisors, lateral incisors, cuspids and bicuspids), showed statistically significant differences among the tested teeth. To date, no studies have reported a difference in root coverage in different morphotypes. However, given the hypothesis of an impact of root curvature on outcomes, it would be of interest to test such an influence in a controlled study.

The level of interdental periodontal support (77) is universally recognized to be of paramount impor-

tance for the outcome of root coverage and is one of the clinical 'indicators' generally used to predict outcome. According to the Miller classification, Class I and II type defects, in which the interdental bone support is intact, have the best potential for complete root coverage. Conversely, only partial root coverage is thought to be achievable in Miller Class III and IV type defects: these are associated with some (from mild to severe) loss of interdental bone support. This hypothesis (or is it a dogma?), however, has been challenged in a recent study (8) on Miller Class III recessions. The authors reported complete root coverage in 38% of patients treated with a modified tunnel/connective tissue graft technique, with or without the additional use of enamel matrix derivative. Evidence on treating Miller Class III and IV defects is both scarce and weak and does not provide any clear indications on the potential of interproximal bone loss to impact on root coverage.

The dimension of the interdental papilla was also investigated in terms of total area and height (apico-coronal dimension). Two published studies reached completely different outcomes. One study, on 33 Miller Class I recessions treated with a coronally advanced flap, demonstrated that the area of the interdental papillae adjacent to the recession defect does not influence the amount of recession reduction and the likelihood of complete root coverage. On the other hand, the height of the papilla does influence complete root coverage: the shorter the papilla, the greater the probability of obtaining complete root coverage (106). Other authors have hypothesized that short papillae could favor coverage because they are normally associated with a flat and thick gingival biotype (88). A second study compared two root-coverage techniques: subepithelial connective tissue graft and acellular dermal matrix allograft. The study reported significant, positive correlations between papilla height and width, and mean root coverage: the higher and wider the papilla, the greater the observed mean root coverage. In addition, a papilla height of 5 mm was consistently associated with complete coverage of the root using both surgical approaches (47).

The amount and thickness of keratinized tissue is generally thought to influence the outcome of root coverage: thick tissues and large amounts of residual keratinized tissue are 'perceived' as favorable. Many clinicians select a coronally advanced flap or a sliding flap when the residual keratinized tissue is well represented, or place a graft under the flap when keratinized tissue is insufficient in thickness and width

(3, 127). However, there is limited evidence to support this approach.

A clinical study (10) tested the influence of flap thickness following coronally advanced flap procedures. The results indicate that flap thickness is significantly ($P < 0.0001$) associated with root coverage. A flap thickness of >0.8 mm was associated with complete root coverage, while a flap thickness of <0.8 mm was associated with partial root coverage. In addition, linear regression analysis showed that with each increase in thickness of 0.1 mm, recession was reduced by approximately 0.2 mm in all treated sites. Therefore, 0.8 mm can be considered as the critical flap thickness above which the expected clinical outcome should be complete root coverage when using a coronally advanced flap alone.

Another study (136) evaluated the relationship between root coverage and the baseline amount of keratinized tissue in laterally positioned and coronally advanced flaps. Multiple logistic regression analysis showed a statistically significant relationship between complete root coverage and the amount of keratinized tissue lateral to the gingival defects: the greater the amount of keratinized tissue, the greater the percentage of root coverage.

Many studies and recent systematic reviews showed the importance of baseline recession depth in the treatment outcome. The results of the meta-analyses of controlled and randomized clinical trials published by Roccuzzo et al. (102) and Clauser et al. (31) showed a relationship between the initial recession depth and the final outcome of the surgical procedure, reporting that 'greater baseline recession depths were always associated with decreased complete root coverage'.

Technique-related factors

Root surface

There is a general consensus in the scientific community that treatment (particularly mechanical treatment) of the exposed root surface is an important component of root-coverage procedures. Various mechanical and/or chemical approaches have been reported in the periodontal literature.

Mechanical root instrumentation (such as root planing or root surface debridement) is first aimed to remove the microbial biofilm and has been attempted with hand and machine-driven instruments. It is important to remember that most Miller Class I and II recession defects are caused by toothbrushing

trauma in patients with good oral hygiene. These recessions are normally associated with low levels of plaque, the presence of clinically healthy gingiva and clean root surfaces. Therefore, the relevance of planing the root surface might be questioned, and more conservative approaches should be adopted (128). A recent randomized, controlled split-mouth clinical study (139) was performed to compare the efficacy of hand and ultrasonic instrumentation in combination with coronally advanced flap therapy in 11 patients with bilateral Miller Class I single recessions. Control root surfaces were planed with curettes, while test roots were instrumented with ultrasonic piezoelectric devices. Hand and ultrasonic root instrumentation were equally effective in terms of root coverage and clinical attachment gain at 6 months postsurgery.

A randomized controlled clinical study compared two mechanical treatment modalities: root planing with curettes vs. polishing with a rubber cup and prophylaxis paste (93). The experimental population consisted of 10 patients with bilateral similar Miller Class I and II single recessions treated with the coronally advanced flap procedure. At 3 months' re-evaluation, the difference in terms of recession reduction between the test and control groups was not statistically significant. In addition, residual hypersensitivity was experienced only in sites treated with root planing. This study suggests that planing of the exposed root surface may be not necessary when shallow recessions caused by traumatic toothbrushing are treated with the coronally advanced flap procedure in patients with high levels of oral hygiene.

Heavy mechanical root instrumentation has been suggested to modify the root surface with the aim of achieving different end results, such as minimizing cementum toxicity (13), smoothing irregularities and grooves in the exposed surface (128), removing root caries lesions (42) and reducing the convexity of the root and the mesio-distal distance between the interproximal spaces (55, 76). Saletta et al. (107) measured the root curvature before and after mechanical instrumentation: vigorous root planing (40 curette strokes) did not substantially modify root curvature, only slightly reduced (3%) the mesio-distal dimensions and slightly flattened (6%) the root surface. Therefore, the use of vigorous root planing is questionable and none of the cited studies report evidence to prove a beneficial influence of extensive root instrumentation on the outcomes of root coverage (128).

The adjunctive effects of different chemical agents, such as citric acid (18, 68), tetracycline-HCl (49),

fibrin glue associated with tetracycline-HCl (123) and sodium hypochlorite (87), in combination with scaling and root planing, have been tested in animal and clinical studies. These agents have been used to remove the smear layer produced by root instrumentation, to expose the collagen fibrils of the dentin matrix facilitating the formation of new connective tissue attachment and to remove cytopathic substances from infected cementum that inhibit human gingival fibroblast growth. Two systematic reviews (85, 102) concluded that there are no significant differences in terms of root coverage between sites treated with root planing alone and sites treated with combined chemical/mechanical treatment. Therefore, chemical root surface conditioning cannot be considered as beneficial for root coverage.

A particular root surface-conditioning approach consists of chemical treatment of the exposed root surface with ethylenediaminetetraacetic acid (EDTA) before the application of enamel matrix derivative. This approach is part of the clinical protocol for enamel matrix derivative application suggested by the manufacturer, even if its efficacy is unknown (25, 41, 46, 74, 79, 89, 115).

A classification of dental surface defects associated with gingival recession (cervical dental caries and/or abrasions) has recently been published (97). This classification is based on the evaluation of two morphological conditions that may be observed on hard dental tissues associated with the occurrence of gingival recession: the presence (Class A) or absence (Class B) of an identifiable cemento-enamel junction; and the presence (+) or absence (-) of a dental surface discrepancy (step). The study was carried out on 1,010 recession defects. Only 469 had an identifiable cemento-enamel junction without any associated step (Class A-: 46%), while 144 sites showed an identifiable cemento-enamel junction associated with a root surface step (Class A+: 14%), 244 had an unidentifiable cemento-enamel junction with a step (Class B+: 24%) and 153 had an unidentifiable cemento-enamel junction without any associated step (Class B-: 15%).

The high prevalence of sites with an unidentifiable cemento-enamel junction and/or with a step require the adoption of clinical strategies to overcome these problems. In daily practice, clinicians should first identify the coronal limit of the potential root coverage: this becomes difficult when the cemento-enamel junction is not identifiable. Predicting and measuring the true and surrogate outcomes becomes impossible if the reference point (i.e. the cemento-enamel junction) is not present. A potential solution

might be the 'reconstruction' of the cemento–enamel junction with restorative dentistry prior to surgery (22, 138). The cemento–enamel junction can be reconstructed with composite resin mimicking a 'normal cemento–enamel junction' (Fig. 2A–D). The methods suggested by the cited authors are obviously based on a 'guess' of the shape and position of the pre-existing cemento–enamel junction, but finally

provide a stable and detectable 'reference' for both the clinician and the patient. Another potential solution is the reconstruction of the cemento–enamel junction after the complete healing of the coronally positioned gingival margin (Fig. 3A–F).

The presence of a step might impair the stabilization of the flap/graft on a flat or concave root surface, thereby requiring a modified treatment

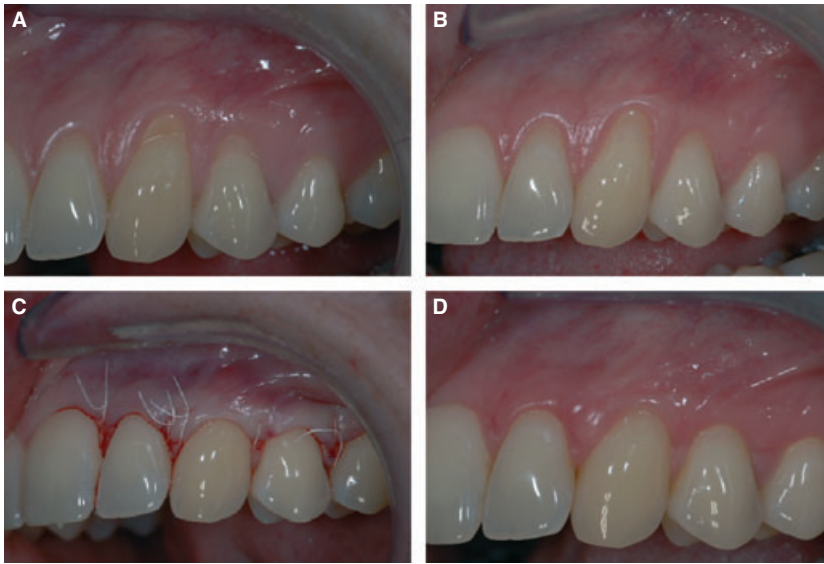


Fig. 2. Root abrasions associated with multiple gingival recessions are restored before root coverage with a coronally advanced flap. (A) Multiple gingival recessions on the maxillary left sextant. The cemento–enamel junction of the cuspid is abraded. (B) Composite restoration of the cemento–enamel junction, performed before surgery. (C) Envelope-type of coronally advanced flap. (D) Clinical outcome after 6 months.

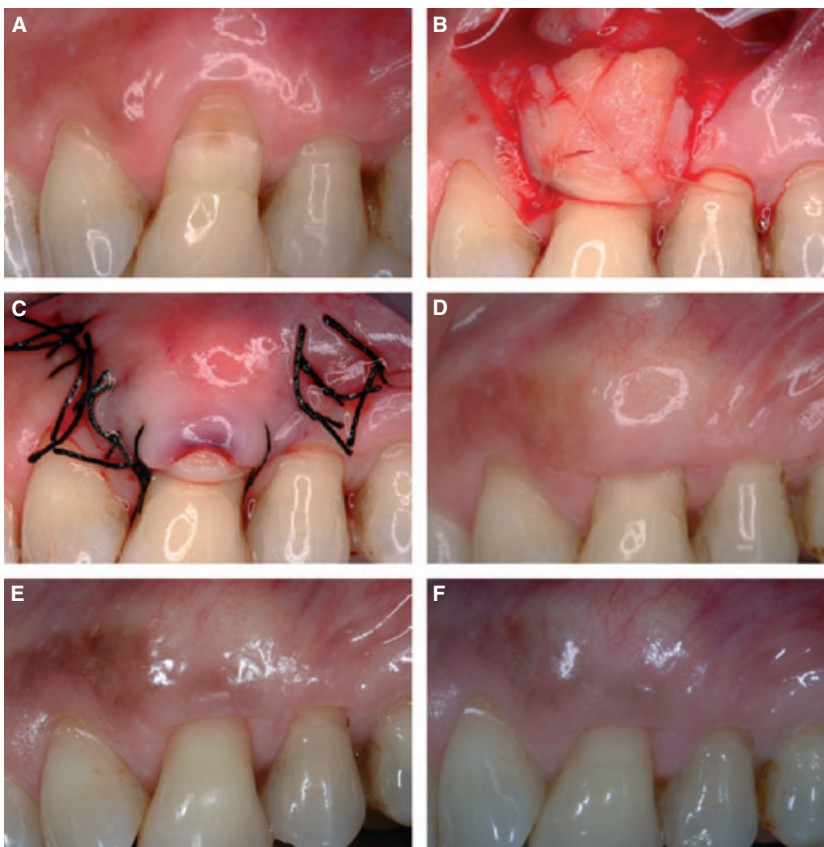


Fig. 3. Coronally advanced flap + connective tissue graft applied on a gingival recession associated with a severe abrasion. (A) Severe recession on the maxillary left cuspid, associated with a severe root step and abrasion of the cemento–enamel junction. The residual gingiva is thick and wide. (B) A connective tissue graft has been sutured on the abraded root surface. (C) A trapezoidal flap with vertical releasing incisions has been coronally advanced. (D) The 1-year clinical outcome. Note that the abraded cemento–enamel junction is visible and has yet to be restored. The root is over-covered and the flat surface determines a flat gingival contour. (E) Clinical appearance after restoration of the cemento–enamel junction with composite resin. (F) Eight-year clinical stability.

approach. Some authors propose the use of barrier membranes on the abraded root surface: the root concavity under a bent barrier is perceived as a benefit because it provides extra space for periodontal regeneration (90). Other authors suggest the application of a thick connective tissue graft positioned to fill the root concavity and finally covered with a coronally advanced flap (22, 75). Lucchesi et al. (70) proposed the reconstruction of the abraded root surface with glass ionomer composite combined with a coronally advanced flap approach. Two randomized clinical studies compared coronally advanced flap plus connective tissue graft (109) or coronally advanced flap alone (110) positioned over a carefully planed root surface against the coronally advanced flap plus connective tissue graft or coronally advanced flap alone positioned over glass ionomer restorations applied during surgery to completely fill the root abrasion. According to the authors, both surgical procedures provide similar soft tissue coverage either on planed or restored root surfaces. The presence of a restoration does not necessarily prevent root coverage but also does not improve the outcome.

Soft tissue

Soft tissue handling is another factor affecting clinical outcomes in mucogingival surgery. Design of the flap, mesio–distal extension, vertical releasing incisions, split-thickness or full-thickness elevation, tension of the flap and coronal positioning of the flap should all be planned by the surgeon before surgery.

One of the relevant aspects strictly associated with flap design is the preservation of a sufficient vascular system to ensure survival of the flap and in particular of the marginal gingiva, which is the farthest part of the flap from the base of the pedicle and lies on an avascular root surface. Wound healing of pedicle flaps on exposed root surfaces depends on the patency of the blood vessels and on anastomoses between capillaries of the flap/recipient area and/or capillaries of connective tissue graft and recipient area/flap. In order to minimize circulatory alterations during root coverage procedures Mörmann & Ciancio (80) suggested that 'flaps should be broad enough at their base to include major gingival vessels and flap preparations to cover avascular areas should not be too thin so that more blood vessels are included in them'. A clinical study (10) reported that thick gingiva was consistently associated with better outcomes in terms of recession reduction and complete root coverage in sites treated with a coronally

advanced flap. The authors speculated that thick marginal tissues could be associated with a more stable vascular system. Another study (136) concluded that wider residual keratinized tissue was associated with greater root coverage in sites treated with laterally positioned, coronally advanced flaps.

The importance of blood supply during healing has been stressed by Burkhardt & Lang (17), who evaluated, in a split-mouth study, the degree of vascularization of connective tissue grafts following the creation of double papilla flaps using microsurgical or macrosurgical approaches. The angiographic evaluation performed immediately after the surgical treatment revealed better vascularization of micro-surgically treated sites compared with macrosurgically treated sites. The authors assumed that 'the sharper and the finer surgical blades, together with finer suture material used in the microsurgical approach, were responsible for the reduced tissue damage'. Similar conclusions were drawn by Francetti et al. (43).

The vascularization of the pedicle flap when performing a coronally advanced flap can be further improved if vertical releasing incisions are avoided. Zucchelli & De Sanctis (134) proposed a surgical technique to treat multiple adjacent recession defects based on an envelope type of flap without vertical releasing incisions. The authors reported excellent clinical results in terms of complete root coverage and optimal esthetic integration of the covering tissue. The same authors have published a study comparing coronally advanced flap therapy, with and without vertical releasing incisions, in the treatment of multiple recessions (140). Both coronally advanced flap techniques were effective in reducing recession depth but the envelope type of coronally advanced flap (without vertical releasing incisions) was associated with an increased probability of achieving complete root coverage and with a better postoperative course. Nevertheless, a recent systematic review reported that data on this issue are still insufficient (27).

An angiographic study on humans supports the hypothesis that the best clinical outcomes, in terms of root coverage, are achievable when the flap is passively adapted and sutured without tension over the exposed root surface (80). Vestibule depth, root prominence, presence of frena and recession depth may influence the passive surgical shift of the coronally advanced flap towards the cemento–enamel junction. If the flap is not completely released, the sutures are positioned to overcome the residual tension to stabilize the flap at the cemento–enamel

junction. As a consequence, sutures that are too tight may damage the residual vascular system of the flap: vessel patency is reduced and neo-vascularization is impaired. In addition, the residual tension of the flap could favor a postoperative apical shift of the gingival margin during the early phase of healing.

This hypothesis was confirmed by a randomized controlled clinical study (94) performed to measure the tension of the coronally advanced flap before suturing and to compare the reduction in recession following coronally advanced flap therapy with or without tension. The statistical analysis showed that minimal flap tension (ranging from 0.0 to 0.4 g) favored recession reduction, while higher tension of the flap (ranging from 4 to 7 g) was associated with lower recession reduction.

The position of the gingival margin in relation to the cemento–enamel junction was proven to be an important factor in achieving complete root coverage with coronally advanced flap therapy. In a pilot study, Pini Prato et al. (93) positioned and sutured the gingival margin 2 mm coronal to the cemento–enamel junction, obtaining complete root coverage. Recently, the same group (95) investigated the influence of the postsurgical position of the gingival margin relative to the cemento–enamel junction on the clinical outcomes of coronally advanced flap therapy. Coronal displacement of the flap of ≥ 2 mm was associated with complete root coverage in 100% of the patients. The results of the logistic regression showed that the greater the coronal displacement of the flap, the greater the recession reduction ($P < 0.0001$) and the greater the probability of obtaining complete root coverage ($P = 0.0003$).

Operator skill is another important factor that can affect the outcomes of periodontal surgery. A consistent center effect has been demonstrated in several studies of periodontal regeneration in intrabony defects (36, 111, 121, 122). Regarding root coverage, a recent multicenter study, comparing coronally advanced flap therapy with coronally advanced flap + connective tissue graft therapy in single recession defects, revealed relevant differences between centers (37). In this study, the center effect was significant in spite of the fact that surgery was performed by skilled periodontists who were specifically trained and calibrated to perform the surgical approaches tested; in addition, the patient population was well balanced and carefully selected according to stringent entry criteria and randomization processes, and the procedures were conducted within a common and strict protocol. The center effect should be

taken into account to explain, at least in part, the high degree of variability frequently observed when studies performed by different clinicians or groups of clinicians are evaluated and statistically analysed, as observed in the meta-analyses from four systematic reviews on root coverage procedures (20, 31, 85, 102). Coronally advanced flaps, with or without the use of a graft, are technique-sensitive procedures that require specific and refined training and a high level of skills to be properly applied.

Surgical procedures

Coronally advanced flap

Single recessions

The coronally advanced flap is based on the coronal shift of soft tissues apical to the exposed root surface (3). The original procedure was described for covering isolated gingival recessions. The design of the flap included 'vertical incisions lateral to the recessed area beginning at a point apical to the papilla tip and extending well into the alveolar mucosa' (3). A sulcular incision and sharp dissection close to the periosteum allowed a split-thickness flap elevation to be performed, reaching the alveolar mucosa. Epithelium was removed from the papillae adjacent to the recession and the flap was coronally positioned and stabilized with interproximal sutures and apico–coronal interrupted sutures to close the vertical releasing incisions. The area was dressed with a periodontal pack.

This overall design of the coronally advanced flap has been developed over time with relevant modifications/improvements coming from animal and human research. Following the suggestion of Mörmann & Ciancio (80), Pini Prato et al. (91) described a flap with divergent releasing incisions to obtain a broad base that included major gingival vessels. The design of the vertical incisions was a 'golf club design' to achieve enough mesio–distal extension of the coronal part of the flap and obtain perfect adaptation to the cemento–enamel junction and the interproximal vascular recipient bed. The starting point of the vertical incisions should be determined before surgery (134): the amount (in mm) of coronal shift of the gingiva necessary to cover the exposed root will indicate the distance from each papilla tip and the starting point of the vertical incisions. This accurate design will allow for a perfect adaptation of the coronal part of the flap to the interdental recipient bed. Pini Prato et al. (91) also suggested a full-thickness elevation

of the gingiva. The clinical study of Baldi et al. (10) proved the relevance of gingival thickness, as thick gingiva was consistently associated with improved outcomes. Flap elevation should therefore be performed through a buccal intrasulcular incision to the bone crest followed by a full-thickness flap elevation beyond the mucogingival junction. Then, sharp horizontal dissection of the periosteum reaching the vertical incisions has to be performed for flap mobilization. Pini Prato et al. (94) demonstrated that flap tension is key to root coverage: tension-free flaps have a higher chance of achieving complete root coverage. Effort should be made to obtain complete relaxation of the flap through proper apical undermining of the alveolar mucosa. The relaxed flap has to be positioned and stabilized to cover the exposed root surface (Fig. 4A–C). The position of the gingival margin influences the final outcomes. Pini Prato et al. (95) showed that complete root coverage following coronally advanced flap therapy was consistently obtained when the flap was positioned 1–2 mm coronal to the cemento–enamel junction. Flap adaptation and stabilization can be achieved through

interdental interrupted sutures or sling sutures. The application of a periodontal pack is today broadly avoided.

Multiple recessions

When multiple gingival recessions are located on adjacent teeth, root coverage should be undertaken with one surgical procedure. The coronally advanced flap described above can be extended to treat multiple recession defects. The pedicle flap should be broad enough to include all of the individual recession defects and the vertical releasing incisions will constitute the mesio–distal limits of the flap. Zucchelli & De Sanctis (134) proposed a modified technique to treat multiple recessions; this technique was based on an envelope flap, aiming to avoid vertical releasing incisions and to better preserve the vascular system and reduce potential scars caused by the vertical incisions (Fig. 5A–D). The design of the envelope flap requires the involvement of one extra tooth mesial, and one extra tooth distal, to the treatment area to allow for sufficient flap mobility. A modified oblique papilla incision is performed to obtain proper adap-



Fig. 4. Coronally advanced flap on a single gingival recession associated with thick residual gingiva. (A) Single gingival recession on the maxillary left bicuspid with thick

residual gingiva. (B) The trapezoidal flap has been sutured coronally to the cemento–enamel junction. (C) One-year clinical outcome.

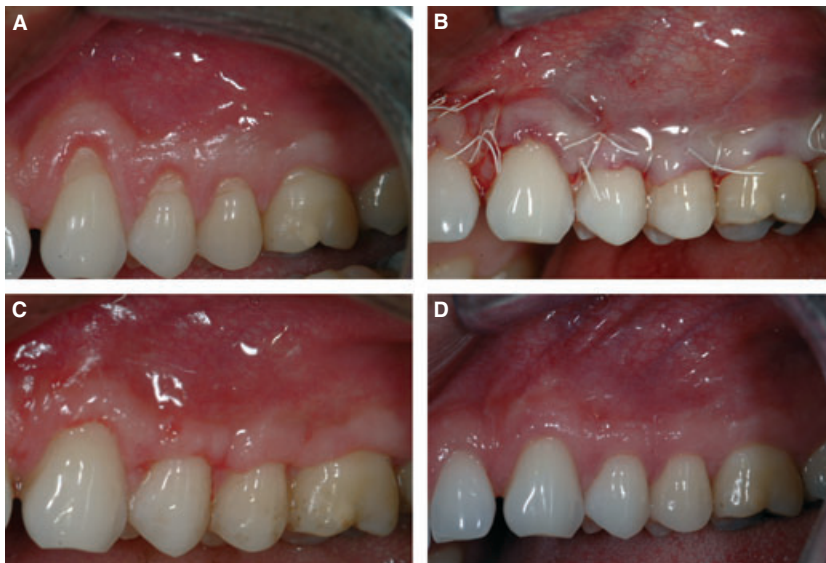


Fig. 5. Coronally advanced flap on multiple gingival recessions associated with thick residual gingiva. (A) Multiple gingival recessions on the maxillary left quadrant. The residual gingiva is thick and wide. (B) An envelope flap has been coronally advanced to cover the cemento–enamel junction of all the involved teeth. (C) The 1-week healing of the flap. (D) The 1-year clinical outcome.

tation of the surgical papilla to the recipient bed. A full-thickness flap, followed by a split-thickness incision beyond the mucogingival junction, is elevated and coronally positioned to cover the cemento–enamel junction. A comparison between the coronally advanced flap, with or without vertical incisions in multiple recessions, demonstrated that both approaches were effective in providing root coverage, but the envelope flap was associated with an increased probability of obtaining complete root coverage and with a better postoperative result (140).

Combined approaches

Coronally advanced flap therapy has been proposed in combination with connective tissue graft, barrier membrane, enamel matrix derivative, acellular dermal matrix, platelet concentrated graft and living tissue-engineered human fibroblast-derived dermal substitute.

Connective tissue graft

Historically, the use of connective tissue grafts, either partially (63) or completely (40, 49, 83, 127) covered by a coronally advanced flap, was suggested. These approaches consisted of thick and large connective tissue grafts sutured close to the cemento–enamel junction and resulted in a high prevalence of complete root coverage. However, even if consistent root coverage occurred, often the esthetic appearance of the treated area was unsatisfactory because of the excessive thickness of the grafted tissue. Recently, some surgical modifications to the original technique have been proposed to improve esthetic outcomes (135). The size, thickness and positioning of the connective tissue graft have been modified accordingly. It has been proposed that a connective graft, 6 mm larger than the recession width, should be applied at the cemento–enamel junction; its apico–coronal dimension is calculated as the distance from the cemento–enamel junction to the bone crest minus the preoperative height of the keratinized tissue. An ideal thickness of

the graft, of about 1 mm, was also suggested. The graft is sutured apical to the cemento–enamel junction at a distance equal to the height of the preoperative keratinized tissue. It has been speculated that this limited thickness and size could improve nutritional exchange between the recipient site, graft and covering pedicle flap as well as the esthetic outcomes. In a randomized controlled clinical study, Zucchelli et al. (135) compared the conventional bilaminar approach with the described novel grafting technique. Outcomes were similar in terms of root coverage, but esthetics and perceptions of patients were much more favorable in the sites treated with the novel approach based on the use of small grafts. The need to open a second surgical site to harvest the graft from the palate adds morbidity to this approach. This approach can be used to treat either single (Fig. 6A–C) or multiple (Fig. 7A–D) recession defects.

Barrier membranes

Barrier membranes have been proposed and tested by many authors (4, 15, 33, 34, 59, 65, 67, 90, 91, 118, 119, 133). Both animal (33) and human histology studies (35) demonstrate the potential of this approach to regenerate periodontium with formation of cementum, bone and periodontal ligament coronal to the baseline position of the gingival margin. The barriers were positioned and fixed coronal to the cemento–enamel junction and fully covered with a coronally advanced flap. The barrier was bent, when possible, to provide space for clot formation on the root surface. Some authors proposed the use of barrier membranes on abraded root surfaces: the root concavity under a bent barrier provided extra space for periodontal regeneration (90). Comparative studies demonstrated no difference between resorbable and nonresorbable barriers in terms of root coverage (102).

Enamel matrix derivative

Animal (48) and human (24, 100) histology studies have proven the potential of enamel matrix deriva-



Fig. 6. Coronally advanced flap + connective tissue graft on a single gingival recession associated with thin residual gingiva. (A) Single gingival recession on the maxillary left

bicuspids with thin residual gingiva. (B) The trapezoidal flap has been coronally positioned to fully cover a connective tissue graft. (C) One-year clinical outcome.



Fig. 7. Coronally advanced flap + connective tissue graft on multiple gingival recessions associated with a narrow band of residual gingiva. (A) Severe multiple gingival recessions on the maxillary right quadrant. The residual gingiva is thick but narrow. (B) A connective tissue graft has been sutured on top of the denuded root surfaces. (C) A flap with a mesial-releasing incision has been coronally advanced to cover the connective tissue graft and the cemento–enamel junction of all the involved teeth. (D) The 1-year clinical outcome.

tive associated with coronally advanced flap therapy to induce periodontal regeneration. This technique has been proposed and tested in several controlled studies (25, 41, 46, 74, 79, 89, 115). Application of enamel matrix derivative is generally accomplished, according to the manufacturer, on the planed and dry root surface. Application of EDTA is generally included in the procedure. The coronally advanced flap procedure is performed in order to completely cover the enamel matrix derivative-treated root surface.

Acellular dermal matrix

Acellular dermal matrix has been proposed to treat recession defects in combination with advanced flaps (51) to avoid the need to harvest connective graft from the palate, thereby eliminating the second surgical site and consequently decreasing morbidity. Acellular dermal matrix is an acellular biocompatible human connective tissue matrix; this allograft of human skin is processed to eliminate the epithelium and all cellular components of the connective tissue and then freeze-dried. The basal membrane is maintained. Several clinical studies have documented root coverage and good esthetic results using acellular dermal matrix (2, 12, 52, 53, 130). A histology study in human samples (39) compared therapy with connective tissue grafts, acellular dermal matrix grafts and coronally advanced flap, and identified the formation of a dense layer of collagen attached to the root surface and unaffected underlying alveolar bone in the three groups. On the basis of these observations the authors concluded that connective tissue graft and acellular dermal matrix grafts can be successfully and safely used to treat exposed root surfaces.

Living tissue-engineered human fibroblast-derived dermal substitute

Another proposal to avoid the use of connective tissue grafts for the treatment of gingival recession defects was published by Wilson et al. (129). The living tissue-engineered human fibroblast-derived dermal substitute is a tissue-engineered human dermal replacement graft manufactured through the three-dimensional culture of human diploid fibroblast cells on a polymer scaffold. In this clinical randomized controlled feasibility study, the effectiveness and safety of human fibroblast-derived dermal substitute compared with connective tissue graft for root coverage was evaluated. At 6 months, there were no statistically significant differences between the two groups and it was concluded that human fibroblast-derived dermal substitute may offer potential as a substitute for connective tissue graft in the treatment of Miller Class I and II recession defects. This needs to be confirmed in independent studies and cost-benefit analyses performed.

Platelet concentrated graft

Platelets contain many autogenous growth factors (including platelet-derived growth factor, insulin-like growth factor and transforming growth factor-beta) that regulate several biologic activities at both genetic and cellular levels. Platelet-rich plasma is highly concentrated in platelets and hence there are many growth factors in a limited volume of plasma (71). *In vitro* studies have demonstrated that growth factors contained in the platelet-rich plasma are involved in the regulation of expression of osteoblast-associated genes (116), regulate the expression of

mineral-associated genes in cementoblasts (112), modulate the proliferation of periodontal cells *in vitro* (86) and stimulate collagen synthesis in periodontal ligament and osteoblastic cells *in vitro* (61). Marx et al. (71) demonstrated that a concentration of 1×10^6 platelets/ml favors the early stages of wound healing. Several clinical studies showed that platelet-rich plasma may enhance early graft maturity, bone density and new bone formation (7, 23, 32, 66, 132).

Different modes of application of platelet concentrated graft under a coronally advanced flap have been proposed in mucogingival surgery. Griffin & Cheung (45) and Cheung & Griffin (30) used a collagen resorbable sponge soaked with platelet-rich plasma, and others (58, 62) applied platelet-rich plasma to a collagen graft, while Huang et al. (56) applied platelet-rich plasma directly onto the planed root surface. A coronally advanced flap is performed in all instances to cover the platelet concentrated graft or platelet-rich plasma.

Clinical outcomes of coronally advanced flap and coronally advanced flap-based approaches

A recent meta-analysis from a systematic review (20) evaluated a total of 794 Miller Class I and II gingival recession defects in 530 patients from 25 randomized controlled trials. Coronally advanced flap was selected as the reference treatment and was compared with the possible combinations (coronally advanced flap + connective tissue graft, coronally advanced flap + enamel matrix derivative, coronally advanced flap + barrier membrane, coronally advanced flap + acellular dermal matrix, coronally advanced flap + platelet concentrated graft and coronally advanced flap + human fibroblast-derived dermal substitute). Complete root coverage was considered as the primary outcome variable; recession reduction and keratinized tissue changes were secondary outcomes. This systematic review confirmed that coronally advanced flap is a safe and reliable approach and is consistently associated with complete root coverage and recession reduction. Results from meta-analyses, however, showed that two combinations (coronally advanced flap + connective tissue graft and coronally advanced flap + enamel matrix derivative) provided better results than coronally advanced flap alone and no other therapy provided better results than coronally advanced flap + connective tissue graft in terms of complete root coverage and recession reduction.

Table 1 presents a summary of the meta-analyses conducted with coronally advanced flap as the control treatment. Coronally advanced flap + connective tissue graft and coronally advanced flap + enamel matrix derivative were associated with a higher probability of obtaining complete root coverage and greater amounts of recession reduction than coronally advanced flap alone. Coronally advanced flap + barrier membrane, coronally advanced flap + acellular dermal matrix and coronally advanced flap + platelet concentrated graft were not any more likely than coronally advanced flap alone to obtain complete root coverage and were not associated with greater amounts of recession reduction.

For keratinized tissue gain, the adjunctive use of connective tissue graft or enamel matrix derivative under a coronally advanced flap was associated with a gain of keratinized tissue compared with coronally advanced flap alone, while combinations of coronally advanced flap + barrier membrane, coronally advanced flap + acellular dermal matrix and coronally advanced flap + platelet concentrated graft did not result in any significant differences compared with coronally advanced flap alone.

As coronally advanced flap + connective tissue graft showed the best outcomes, Cairo et al. (20) performed additional comparisons considering coronally advanced flap + connective tissue graft as the control surgical procedure (Table 2). Single studies compared coronally advanced flap + enamel matrix derivative and coronally advanced flap + human fibroblast-derived dermal substitute vs. coronally advanced flap + connective tissue graft, and reported no significant differences in terms of complete root coverage. No significant differences in complete root coverage were reported when comparing coronally advanced flap + barrier membrane and coronally advanced flap + acellular dermal matrix vs. coronally advanced flap + connective tissue graft, although a trend favoring coronally advanced flap + connective tissue graft was detected. In terms of recession reduction, the meta-analyses reported better results for coronally advanced flap + connective tissue graft vs. coronally advanced flap + barrier membrane, but no significant differences were reported vs. coronally advanced flap + acellular dermal matrix; for this comparison, however, the test for heterogeneity was statistically significant ($P = 0.002$). Comparisons in terms of recession reduction between coronally advanced flap + enamel matrix derivative and coronally advanced flap + human fibroblast-derived dermal substitute vs. coronally advanced flap + connective tissue graft were not

Table 1. Outcomes from meta-analyses conducted with coronally advanced flap as the control treatment (20)

	Coronally advanced flap alone vs.				
	Coronally advanced flap + connective tissue graft	Coronally advanced flap + enamel matrix derivative	Coronally advanced flap + barrier membranes	Coronally advanced flap + acellular dermal matrix	Coronally advanced flap + platelet concentrated graft
Complete root coverage					
No. of randomized clinical trials	Two	Four	One	Two	One
Significance (<i>P</i> -value)	0.03	0.003	0.41	0.31	0.79
Odds ratio	2.49	3.89	0.58	4.83	1.25
95% confidence interval	1.10–5.68	1.59–9.50	0.16–2.08	0.23–99.88	0.23–6.71
Recession reduction					
No. of randomized clinical trials	Two	Five	Two	Two	One
Significance (<i>P</i> -value)	0.005	0.002	0.11	0.29	0.57
Mean difference (mm)	0.49	0.58	–0.27	0.60	–0.20
95% confidence interval	0.14–0.83	0.14–0.83	–0.60 to 0.06	–0.52 to 1.73	–0.89 to 0.49
Keratinized tissue					
No. of randomized clinical trials	Two	Five	Two	Two	One
Significance (<i>P</i> -value)	0.0001	0.0007	0.30	0.19	0.38
Mean difference (mm)	0.73	0.42	0.15	0.31	–0.30
95% confidence interval	0.35–1.10	0.18–0.66	–0.13 to 0.42	–0.15 to 0.78	–0.97 to 0.37

Comparative test treatments were connective tissue graft + coronally advanced flap, coronally advanced flap + enamel matrix derivative, coronally advanced flap + barrier membranes, coronally advanced flap + acellular dermal matrix and coronally advanced flap + platelet concentrated graft.

possible owing to the methods of data presentation in the original articles (74, 129), even if no statistically significant difference was reported by the authors. Therefore, no combined therapy was more effective than coronally advanced flap + connective tissue graft for achieving complete root coverage and recession reduction.

Only two comparisons were possible for keratinized tissue gain. Coronally advanced flap + connective tissue graft resulted in better outcomes when compared with coronally advanced flap + barrier membrane and coronally advanced flap + acellular dermal matrix. For the comparison with coronally advanced flap + barrier membrane, the test for heterogeneity was statistically significant ($P < 0.00001$). Comparisons in terms of keratinized tissue gain between coronally advanced flap + enamel matrix derivative and coronally advanced flap + human fibroblast-derived dermal substitute vs. coronally advanced flap + connective tissue graft were not possible because of the data-presentation methods in

the original articles (74, 129). However, McGuire & Nunn (74) reported greater gain of keratinized tissue for coronally advanced flap + connective tissue graft than for coronally advanced flap + enamel matrix derivative ($P < 0.001$) 1 year following therapy, while Wilson et al. (129) reported no difference. Therefore, no therapy was more effective than coronally advanced flap + connective tissue graft in achieving keratinized tissue gain.

Healing dynamics and long-term outcomes after coronally advanced flap or combination therapy

What happens to the gingival margin shortly after a root coverage procedure? Following coronally advanced flap therapy of single recession defects, Pini Prato et al. (93) reported that the gingival margin, sutured, on average, 1 mm coronal to the cemento–enamel junction, remained stable at week 1, but

Table 2. Outcomes from meta-analyses conducted with coronally advanced flap + connective tissue graft as the control treatment (20)

	Coronally advanced flap + connective tissue graft vs.			
	Coronally advanced flap + enamel matrix derivative	Coronally advanced flap + barrier membranes	Coronally advanced flap + acellular dermal matrix	Coronally advanced flap + human fibroblast-derived dermal substitute
Complete root coverage				
No. of randomized clinical trials	One	Six	Four	One
Significance (<i>P</i> -value)	0.31	0.06	0.06	1.00
Odds ratio	2.31	0.45	0.49	1.00
95% confidence interval	0.45–11.74	0.20–1.04	0.23–1.03	0.02–50.40
Recession reduction				
No. of randomized clinical trials	One	Six	Four*	One
Significance (<i>P</i> -value)	–	0.008	0.24	–
Mean difference (mm)	–	–0.38	–0.40	–
95% confidence interval	–	–0.65 to –0.10	–1.07 to 0.26	–
Keratinized tissue				
No. of randomized clinical trials	–	Six*	Four	–
Significance (<i>P</i> -value)	–	0.004	0.004	–
Mean difference (mm)	–	–1.18	–0.90	–
95% confidence interval	–	–1.98 to –0.39	–1.51 to –0.28	–

Comparative test treatments were coronally advanced flap + enamel matrix derivative, coronally advanced flap + barrier membranes, coronally advanced flap + acellular dermal matrix and coronally advanced flap + human fibroblast-derived dermal substitute.

*Test for heterogeneity was statistically significant.

shifted apically from weeks 2 to 4, uncovering the cemento–enamel junction in 60% of the sites with an average shift of 1.5 ± 0.6 mm. From week 4 to week 12 after the procedure, the gingival margin remained stable. Cortellini et al. (37) tested the stability of the gingival margin in a controlled clinical trial comparing the potential benefit of adding a graft under a flap with coronally advanced flap therapy alone, in single gingival recession defects. At week 1, the cemento–enamel junction was visible in five (12%) of the patients treated with a coronally advanced flap and in three (7%) of the patients treated with a coronally advanced flap + connective tissue graft. There was a steady increase in the number of patients with a visible cemento–enamel junction over the following 3 weeks. The increase in the number of sites with a visible cemento–enamel junction was greater in the coronally advanced flap-treated sites; this trend was further confirmed at the 3- and 6-month examination time-points, ending at 6 months with 27 exposed cemento–enamel junctions out of 43 coronally ad-

vanced flap-treated sites and with 17 exposed cemento–enamel junctions out of 42 coronally advanced flap + connective tissue graft-treated sites (Fig. 8). The tendency for an apical shift of the gingival margin to occur after surgery was confirmed in two case series on single recession defects published by Baroffio et al. (11) in coronally advanced flap + connective tissue graft cases and published by Centra & Gionso (26) in cases of coronally advanced flap therapy alone.

Long-term studies show different patterns in the tendency for recurrence of recession following different root coverage procedures. Leknes et al. (65) reported severe recurrence of gingival recession in a 6-year study of sites treated either with coronally advanced flap or with coronally advanced flap + bioresorbable barriers. At 6 months, five sites treated with coronally advanced flap + barrier membrane and 10 sites treated with coronally advanced flap alone were completely covered in a population of 11 bilateral single recession defects. At 6 years,

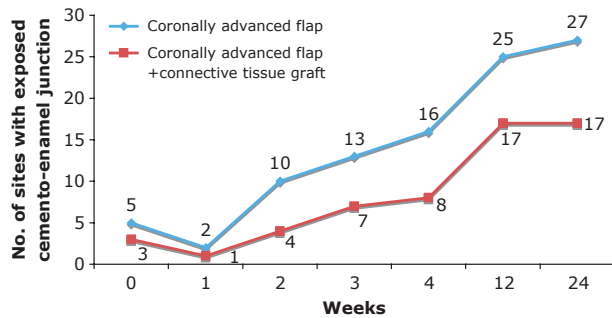


Fig. 8. Number of sites with exposed cemento–enamel junction (indicated as numbers next to points in the graph) in patients treated with coronally advanced flap (blue) and coronally advanced flap + connective tissue graft (red). The graph shows a tendency for a progressive increase in the number of sites with exposed cemento–enamel junction through time for both groups. The sites receiving a connective tissue graft demonstrate greater stability. Modified from Cortellini et al. (37).

only two sites treated with barriers and one site treated with coronally advanced flap alone were still completely covered. Nickles et al. (84) compared sites treated with coronally advanced flap + a bio-resorbable barrier to sites treated with coronally advanced flap + connective tissue graft. After 10 years, stability of root coverage was significantly better in the sites treated with coronally advanced flap + connective tissue graft. In other words, the sites treated with a barrier membrane underwent a greater apical shift of the gingival margin over time. A 14-year study of 22 single recession defects treated with coronally advanced flap alone similarly reported a consistent apical shift of the gingival margin in 39% of the cases (96). In a 5-year evaluation of a case series treated with the envelope type of coronally advanced flap on multiple recession defects, Zucchelli & De Sanctis (137) reported a slight shift of the gingival margin compared with the 1-year data. The amount of long-term recurrence, however, was very limited. In fact, complete root coverage was observed in 88% of the patients at 1 year, and was reduced to 85% at 5 years. In contrast, a long-term comparative study (98) of multiple recession defects treated with coronally advanced flap alone or with coronally advanced flap + connective tissue graft showed a consistent shift of the gingival margin over time in the coronally advanced flap-treated sites, whereas the coronally advanced flap + connective tissue graft-treated sites showed a tendency for a coronal shift of the gingival margin (Figs 9, 10A–E, 11C–D).

The reported studies seem to indicate a possible beneficial role of adding a graft under a flap to in-

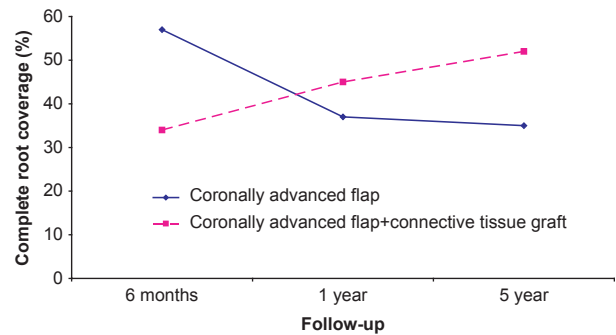


Fig. 9. Number of sites with complete root coverage in patients treated with coronally advanced flap (blue) and coronally advanced flap + connective tissue graft (red). The graph shows a tendency of a progressive apical shift through time in the coronally advanced flap-treated sites, whereas the sites receiving a connective tissue graft demonstrate a tendency for improved root coverage. Modified from Pini Prato et al. (98).

crease the stability of the gingival margin over time. Interestingly, a trend of the so-called ‘creeping attachment’ of grafted sites was reported in a 27-year follow-up study (1). The authors reported a significant coronal shift of the gingival margin in grafted sites, while observing an apical shift of the gingival margin at contralateral nongrafted sites.

In summary, it is apparent that the position of the gingival margin tends to shift apically after surgery in the short term after coronally advanced flap therapy alone or in combination with other procedures. The greatest recurrence of recession seems to occur after coronally advanced flap therapy alone, while the interposition of a graft seems to enhance the stability of the gingival margin. Grafted sites, over the long term, show a tendency for a coronal shift of the gingival margin, while the coronally advanced flap-treated sites confirm a tendency for recurrence of recession similar to sites treated with coronally advanced flap + barrier membrane.

Patient-related outcomes and side effects

Dentinal hypersensitivity

Very few studies have evaluated dentinal hypersensitivity following root coverage procedures. Cortellini et al. (37) compared coronally advanced flap + connective tissue graft vs. coronally advanced flap alone, and reported no statistically significant differences for dental hypersensitivity (12% in the test group and 12% in the control group) 6 months following



Fig. 10. Coronally advanced flap + connective tissue graft on multiple gingival recessions associated with a narrow band of residual gingiva and stability over time. (A) Recessions on the upper maxillary cuspid and bicuspid. The residual gingiva is thin and narrow. (B) A connective tissue graft has been sutured on top of the denuded root surfaces. (C) A trapezoidal flap has been coronally advanced to cover the connective tissue graft and the cemento–enamel junction of all the involved teeth. (D) The 1-year clinical outcome. (E). Clinical stability after 5 years.

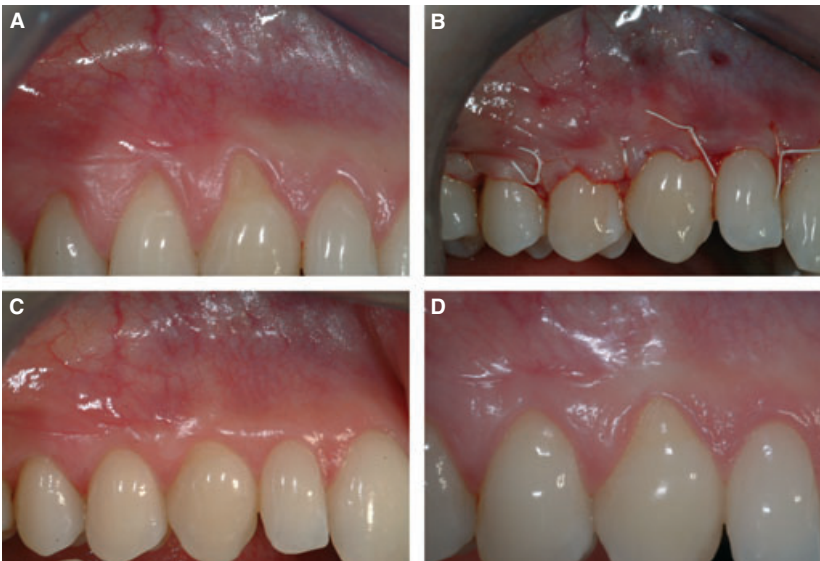


Fig. 11. Coronally advanced flap on multiple gingival recessions associated with a narrow band of residual gingiva and recurrences over time. (A) Contralateral side of the patient described in Fig. 10, presenting with gingival recessions on the maxillary right cuspid and bicuspid. The residual gingiva is thin and narrow. (B) An envelope flap has been coronally advanced to cover the cemento–enamel junction of all the involved teeth. (C) The 1-year clinical outcome. (D) Gingival recession recurrence after 5 years.

therapy. McGuire & Nunn (74) reported dentinal hypersensitivity in only one patient treated with coronally advanced flap + enamel matrix derivative and no dentinal hypersensitivity for a coronally advanced flap + connective tissue graft 1 year following therapy. Pini Prato et al. (93) reported reduced hypersensitivity in sites treated with prophylaxis compared to sites treated with root planing following coronally advanced flap therapy.

Esthetics

Some studies have evaluated esthetic satisfaction following therapy. Romagna-Genon (103) compared coronally advanced flap + barrier membrane vs. coronally advanced flap + connective tissue graft in a split-mouth study, and reported that one patient was not satisfied with either treatment. In a study by Wang et al. (126) a double esthetic evaluation was

performed by a periodontist blinded to the treatment and by the patients. The periodontist rated treatment outcomes at 6 months, concluding that 15 out of 16 barrier membrane sites and 11 connective tissue graft sites had an excellent colour match. Patient satisfaction with esthetics (colour match, overall satisfaction and amount of root coverage) was the same for both treatments, even if greater overall satisfaction was expressed for barrier membrane sites. Aichelmann-Reidy et al. (2) compared coronally advanced flap + acellular dermal matrix vs. coronally advanced flap + connective tissue graft in a split-mouth study in 22 patients, performing a double esthetic evaluation (blinded clinician and patients). The clinician considered that sites with coronally advanced flap + acellular dermal matrix were associated with better results in 11 patients, while the outcomes in the other 11 patients were similar to those of coronally advanced flap + connective tissue graft. Nine patients out of 22 considered coronally advanced flap + acellular dermal matrix to be associated with better esthetics; in 12 patients outcomes were considered similar to coronally advanced flap + connective tissue graft and the remaining patient preferred the side treated with coronally advanced flap + connective tissue graft. Keloid formation was reported in one patient treated with a coronally advanced flap + connective tissue graft. Zucchelli et al. (135) compared the esthetic outcome of a conventional thick connective tissue graft associated with coronally advanced flap with the outcome after treatment with a thinner and smaller graft. Both procedures resulted in similar root coverage, but the esthetic appearance of the sites treated with the thin graft got a higher score. The same authors (140) compared two types of coronally advanced flaps on multiple recession defects: the envelope type vs. the flaps with vertical releasing incisions. Root coverage was similar with both procedures but the envelope type resulted in better esthetics.

Adverse side effects

Pain and complications are unusual following root coverage procedures. Da Silva et al. (40) reported no complications when comparing coronally advanced flap + connective tissue graft vs. coronally advanced flap. Cortellini et al. (37) reported three cases of haematoma in 43 patients treated with coronally advanced flap and five cases of haematoma in 42 patients treated with coronally advanced flap + connective tissue graft. A higher number of patients with postoperative swelling was reported for the coronally ad-

vanced flap + connective tissue graft group, and these differences were statistically significant (coronally advanced flap + connective tissue graft: 32.2 ± 28.4 ; and coronally advanced flap, 17.8 ± 19.9 ; data obtained using a visual analog scale; $P = 0.0068$). No statistically significant difference for pain was reported between the two groups (23.8 ± 19.4 for coronally advanced flap and 31.4 ± 24.6 for coronally advanced flap + connective tissue graft; data obtained using a visual analog scale; $P = 0.0811$). In studies using barrier membranes, a frequent complication was membrane exposure: Amarante et al. (4) reported the exposure of several membranes in coronally advanced flap + barrier membrane sites, while Lins et al. (67) reported the exposure of all membranes in all treated sites (10/10). In studies comparing coronally advanced flap + barrier membrane and coronally advanced flap + connective tissue graft, membrane exposure was reported as a possible complication in seven of 15 patients (Jepsen et al. (59)), in two of 12 patients (Trombelli et al. (125)) and in five of 12 patients (Tatakis & Trombelli (118)). Jepsen et al. (59) reported a similar incidence of postoperative pain for both treatments (five of 15 patients). Tatakis & Trombelli (118) reported seven cases of swelling in 12 patients treated with a coronally advanced flap + barrier membrane but none for patients treated with a coronally advanced flap + connective tissue graft. No complications for a coronally advanced flap + barrier membrane were reported by Wang et al. (126). Instead, they reported one swelling and one ecchymosis in the coronally advanced flap + connective tissue graft group. Romagnan-Genon (103) described postoperative discomfort at the palatal donor site for the connective tissue graft. Sites treated with barrier membrane were more frequently symptom-free. None of the patients reported exposure of the membrane. No complications were reported in comparisons between coronally advanced flap + enamel matrix derivative vs. coronally advanced flap (79), coronally advanced flap + acellular dermal matrix vs. coronally advanced flap (38, 130) and coronally advanced flap + acellular dermal matrix vs. coronally advanced flap + connective tissue graft (60). When comparing coronally advanced flap + enamel matrix derivative vs. coronally advanced flap + connective tissue graft, McGuire & Nunn (74) reported higher discomfort for the connective tissue graft procedure ($P = 0.011$) 1 month after therapy.

No statistically significant differences for complications were reported when comparing coronally advanced flap + platelet concentrated graft vs. coronally advanced flap (56), using a wound healing index.

Flow charts and discussion

In the era of evidence-based medicine, clinicians are invited to adopt evidence-based decisions for therapy. However, it is apparent that evidence-based decision-making is lacking in many areas of periodontal therapy, including decisions about achieving root coverage at recession defects. The lack of evidence means that clinical experience is used when making clinical decisions. The literature survey performed in this review attempts to provide clinicians with enough scientific and clinical support to take proper decisions. References to support the following flow charts have been reported earlier in this review.

A reasonable starting point for a flow chart is to set the outcomes of therapy (Fig. 12). Treatment of recession is often undertaken to satisfy the esthetic demands of patients: the main outcome should therefore be esthetic satisfaction of the patient (37, 74, 93). However, scientific background on this 'true' outcome is very scarce. A number of research groups are now proposing novel 'evaluation scales' of esthetics that need validation and adoption in controlled studies (21, 104): these will probably help clinicians in the future to choose the proper approach and acknowledge patient desires. Owing to this lack of information, we are therefore forced to make decisions based on 'surrogate outcomes'. Complete root coverage is the one mostly used, along with recession reduction. Another commonly re-

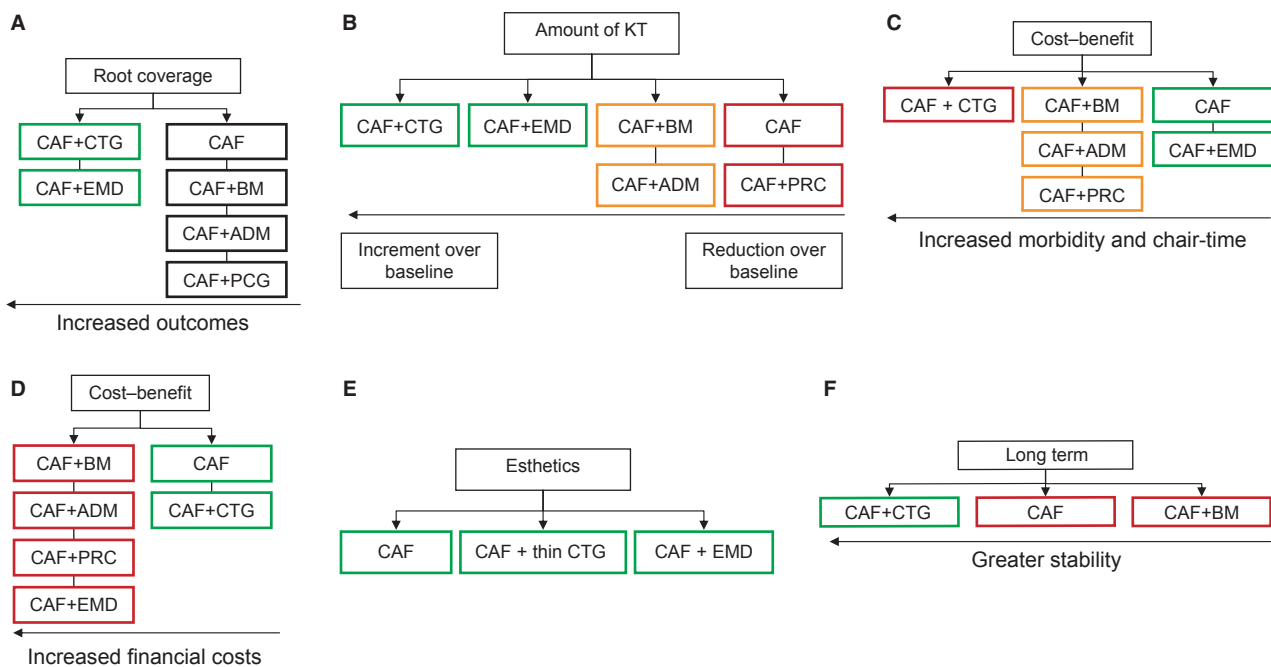


Fig. 12. Objectives of therapy. (A) When the objective of therapy is root coverage, meta-analyses demonstrate that the combinations of coronally advanced flap (CAF) + connective tissue graft (CTG) and coronally advanced flap + enamel matrix derivative (EMD) (green) result in the best clinical outcomes. (B) When the objective of therapy is increased keratinized tissue (KT), meta-analyses demonstrate that adding a graft or even enamel matrix derivative under a flap (green) results in increased keratinized tissue. The amount of keratinized tissue is slightly reduced over time when a coronally advanced flap alone or with platelet-rich concentrate (PRC) (red) is used. There is a minor reduction in keratinized tissue when a barrier membrane (BM) or an acellular dermal matrix (ADM) (orange) is added to a coronally advanced flap. (C) When considering the cost-benefit ratio, greater morbidity and chair-time are associated with some combinations (red and orange) with

respect to a coronally advanced flap, alone or together with enamel matrix derivative (EMD) (green). These results were supported by controlled studies. (D) When evaluating the cost-benefit ratio, clinicians should consider that increased financial costs are associated with the combinations in red with respect to a coronally advanced flap, alone or with a connective tissue graft (green). These results were supported by expert opinions. (E) According to existing evidence, the three suggested procedures (green) do result in the best esthetic outcomes. These results were supported by controlled studies. (F) Considering the long-term stability of therapy, results obtained with coronally advanced flap + connective tissue graft (green) are reportedly more stable over time than results obtained with coronally advanced flap or coronally advanced flap + barrier membrane (red). These results were supported by controlled studies. PCG, platelet concentrated graft.

ported outcome of interest is an increase in keratinized tissue.

Overall, the results of meta-analyses showed that two treatment combinations – coronally advanced flap + connective tissue graft and coronally advanced flap + enamel matrix derivative – provide the best clinical outcomes for both complete root coverage and recession reduction (Fig. 12A), while coronally advanced flap + connective tissue graft results in the greatest gain of keratinized tissue, followed by coronally advanced flap + enamel matrix derivative (Fig. 12B) (20). In other words, coronally advanced flap + connective tissue graft ‘wins the game’ for all the most common surrogate outcomes and should therefore be considered the treatment of choice. Coronally advanced flap + enamel matrix derivative therapy is a potential alternative. The other combinations tested do not offer advantages over coronally advanced flap therapy alone (20).

Our decision-making process, however, should include clinical considerations regarding patient morbidity and potential side effects that are inherent to the second surgical site required when harvesting a graft from the palate (Fig. 12C) (37, 40, 103). The desire to reduce morbidity, side effects and also the surgical chair-time creates challenges and suggests adoption of the second-best combination therapy (coronally advanced flap + enamel matrix derivative) or of one of the other tested combinations with acellular dermal matrix, barrier membrane or platelet-rich plasma (4, 38, 56, 59, 60, 67, 74, 79, 130).

All of these combinations, however, are based on the use of commercial products that will increase the financial cost of the treatment (Fig. 12D). Considerations about cost–benefit should therefore be introduced into our decision-making process; however, cost–benefit analyses are still absent in the published literature. Adoption of coronally advanced flap therapy alone would slightly compromise the outcomes, but would reduce morbidity, surgical chair-time and costs (37).

Looking at the limited evidence on esthetics, it is apparent that coronally advanced flap alone, coronally advanced flap + enamel matrix derivative and coronally advanced flap + thin connective tissue graft are the techniques which achieve the best esthetic outcomes (Fig. 12E) (2, 103, 126, 135, 140).

Other relevant information for the choice of which procedure to use comes from long-term studies indicating a greater stability of coronally advanced flap + connective tissue graft compared with coronally advanced flap alone or coronally advanced

flap + barrier membrane (65, 84, 96). This evidence adds strong support to the placement of a graft under a coronally advanced flap to improve both short-term and long-term outcomes (Fig. 12F).

Figure 12A–F is mainly supported by meta-analyses based on randomized controlled trials that provide substantial support for our decision-making process (20). However, we should remember that the random assignment of a therapy cannot satisfy the requirements of each single clinical case. In other words, the presurgical analysis of every patient should incorporate information that cannot be fully exploited by the meta-analytic process of randomized controlled trials. This individual, clinically oriented analysis is presented in Figs 14 and 15.

The second step in our decision-making process is trying to forecast the outcomes by assessing patient, tooth and defect/site prognostic factors. Figure 13 lists the factors that researchers and clinicians believe are relevant to root coverage. Most of these are not supported by evidence (yellow).

Among the potential patient factors, only smoking has sufficient evidence to indicate a clear, negative effect on root coverage (28). The potential influence of oral hygiene habits (19) relies on the hypothesis that improper toothbrushing can cause recession: the same aggressive oral hygiene habit might impair the short-term and long-term outcomes of surgery. Age, gender and race have not been explored in well-de-

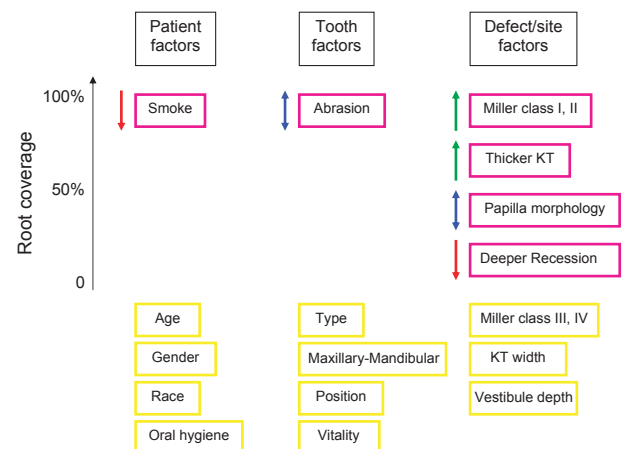


Fig. 13. Factors affecting root coverage. Patient, tooth and defect / site factors are clustered at two levels. The factors supported by evidence are shown in violet boxes. Some of the factors generally perceived as relevant by experts, but without evidence, are shown in yellow boxes. The coloured arrows indicate the impact of each supported factor on root coverage, according to the existing literature: red arrow = negative impact; blue arrow = no difference; green arrow = positive impact; KT = keratinized tissue.

signed studies: in other words, we do not know their influence.

Among the tooth factors, there is evidence to indicate that the presence of abrasions does not impair root coverage. Most clinicians believe that tooth position has an influence on root coverage: rotated and buccally positioned teeth could make it more difficult to perform the procedure. There are also hypotheses that a poorer outcome might be achieved with mandibular teeth and larger units (such as molars). There is no real evidence regarding the influence of tooth vitality on outcomes (14, 73, 81, 82).

Among the defect/site factors, there is evidence to indicate the potential for complete root coverage of Miller Class I and Class II defects (77). Evidence indicates that thicker gingiva is associated with a greater probability of obtaining complete root coverage by therapy with a coronally advanced flap (3, 127). There is limited evidence indicating that even in Class III defects, complete root coverage might be achieved (8). There is conflicting evidence on papilla height and width (47, 88, 106): some authors report better outcomes with shorter papillae (with coronally advanced flap), whereas others report better outcomes with longer papillae (with coronally advanced flap + connective tissue graft). Recession depth is inversely correlated with root coverage: the deeper the recession defect, the more difficult it is to achieve the root coverage. Vestibule depth is indicated as relevant by most of the experts: the shallower the vestibule, the more difficult the coronal positioning of the flap.

In summary, reduced outcomes are to be expected in smokers with aggressive oral hygiene habits, and at deep recessions with thin gingiva, located in the lower jaw in buccally positioned and rotated teeth with shallow vestibules.

Analysis of the tooth structure is first directed to check for the presence of the cemento–enamel junction (Fig. 14). If the cemento–enamel junction is intact or only slightly abraded, no presurgical treatment is required. If the cemento–enamel junction is missing (39% prevalence) (97), we do not have the coronal reference available to indicate the level of maximum potential root coverage. In this instance, it is suggested that the cemento–enamel junction should be rebuilt with composite before surgery (ensuring that this is not plaque-retentive) (22, 138). A second, frequent, observation (38% prevalence) is the presence of a step (97). The step, caused by the aggressive brushing habit of the patient, can be very deep, causing a problem of adaptation of the coronally advanced flap. In this instance, three potential

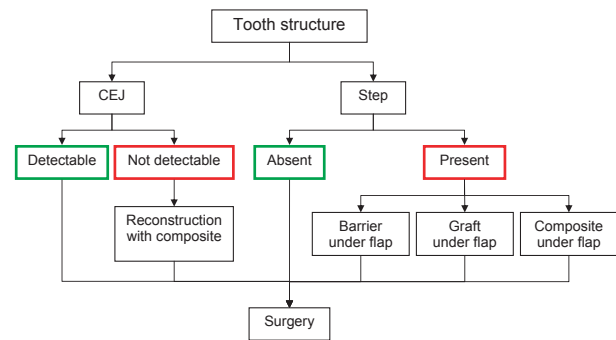


Fig. 14. Analysis of the tooth structure. If the cemento–enamel junction (CEJ) is detectable (green) and no steps are present (green), surgery can be undertaken without any additional treatment. If the cemento–enamel junction is not detectable (red) and/or a step is present (red), an additional approach is suggested before flap suturing. Supported by controlled studies.

solutions have been proposed and successfully tested: (i) placement of a connective tissue graft (22, 75) or (ii) a barrier (90) under a coronally advanced flap or (iii) the presurgical reconstruction of the missing root structure with composite (109, 110). In many instances, a missing cemento–enamel junction is associated with a step (24% prevalence) (96). This condition requires the adoption of one of the suggested measures to correct both the anatomical deformities.

The nature of the periodontal soft tissues is relevant to the surgical approach. There is a common clinical ‘feeling’ that thick and wide residual gingiva favors root coverage (Fig. 15). The experts tend to suggest the use of coronally advanced flap alone in this instance. When the residual soft tissue is narrow and thin, the adjunctive use of a graft is generally advocated. One study (10) has supported the importance of flap thickness when undertaking a coronally advanced flap procedure, but no studies have directly tested the impact of the width of the residual gingiva and the outcomes of coronally advanced flap alone or combination therapy. Observations from short-term and long-term studies discussing the healing dynamics and the long-term stability of the gingival margin, however, seem to confirm that the additional use of a graft under a flap improves the short-term and long-term outcomes (11, 26, 37, 93). Other combination therapies (enamel matrix derivative, acellular dermal matrix and platelet-rich plasma) might help to achieve the same additive effect. The use of barrier membranes does not improve the outcomes over and above those achieved by the coronally advanced flap procedure alone (20).

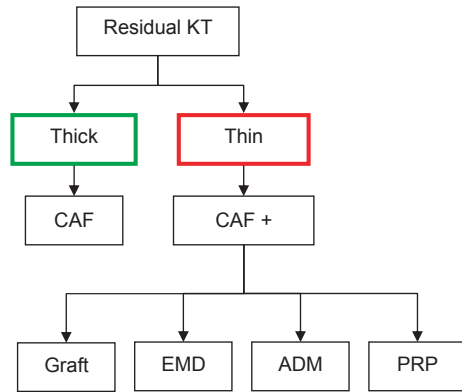


Fig. 15. Analysis of periodontal tissues. If residual keratinized tissue (KT) is thick (green), coronally advanced flap (CAF) therapy alone can result in predictable root coverage. If keratinized tissue is thin (red) a combination therapy might be indicated. Supported by expert opinions. EMD, enamel matrix derivative; ADM, acellular dermal matrix; PRP, platelet-rich plasma.

Mechanical treatment of root surfaces at surgery is the treatment of choice (Fig. 16). Evidence indicates that either hand instruments or powered instruments, including prophylaxis, result in similar outcomes (93, 128, 139). There is no evidence to support any beneficial effect of chemical root conditioning in addition to mechanical debridement (85, 102).

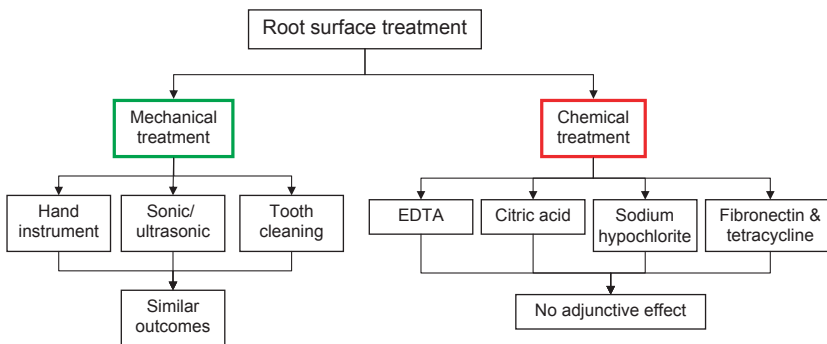


Fig. 16. Root surface treatment. Mechanical instrumentation (green) performed with different approaches is considered the treatment of choice. Chemical therapy (red) does not provide any adjunctive benefit. Supported by controlled studies. EDTA, ethylenediaminetetraacetic acid.

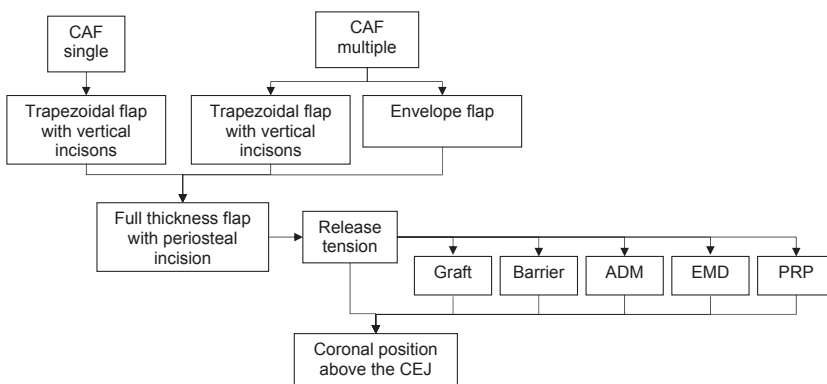


Fig. 17. Surgical procedure. Technical tips to perform a coronally advanced flap (CAF) either on single or multiple recession or a combination therapy. Supported by controlled studies. ADM, acellular dermal matrix; EMD, enamel matrix derivative; PRP, platelet-rich plasma; CEJ, cemento-enamel junction.

(20). From a surgical standpoint, all these materials or products are applied on the denuded and debrided root surface, sutured when indicated and fully covered with the coronally advanced flap.

Conclusions

It is clear that much relevant information is still missing in the published literature.

Evidence indicates that the use of a graft under a coronally advanced flap results in the best short-term and long-term outcomes in terms of root coverage and gain in keratinized tissue with the highest prevalence of success. It would therefore appear easy to suggest that clinicians adopt coronally advanced flap + connective tissue graft for root coverage. On the other hand, harvesting a graft from the palate adds morbidity, lengthens surgical chair-time and requires increased surgical skills. It is evident that treatment with a coronally advanced flap alone is less invasive for the patient, and requires less chair-time and probably less surgical skill. In addition, evidence shows that coronally advanced flap therapy in many instances results in complete root coverage and is stable over time. It would therefore be desirable to apply coronally advanced flap when indicated. Unfortunately, the key information – to be able to forecast when coronally advanced flap will be successful – is still missing. Many ‘experts’ support the hypothesis that therapy with coronally advanced flap alone can be successfully applied when the residual gingiva is thick and wide. Accordingly, the adjunctive use of a graft could be restricted to sites with thin and narrow residual gingiva. A potential alternative is the use of enamel matrix derivative.

Another indication for placing a graft under a flap is the presence of a step on the root surface. An alternative to placing a connective tissue graft might be the use of enamel matrix derivative as this results in better outcomes than coronally advanced flap alone and is equally effective as coronally advanced flap + connective tissue graft in terms of root coverage.

If one of the objectives is keratinized tissue gain, however, clinicians should choose a graft. Other potential alternatives to a graft are acellular dermal matrix, platelet concentrated graft and human fibroblast-derived dermal substitute. Evidence, however, does not indicate an advantage of these approaches over coronally advanced flap alone. The use of enamel matrix derivative, acellular dermal matrix, barrier membrane, platelet concentrated graft and human fibroblast-derived dermal substitute reduce

morbidity and chair-time, but increases the financial cost of therapy.

Clinicians should make their decisions after defining the desired short-term and long-term outcomes, having completed a careful presurgical analysis and having discussed with the patient the impact of morbidity and biologic/economic costs in addition to the potential benefits of therapy.

Acknowledgments

This study was supported by the Accademia Toscana di Ricerca Odontostomatologica (ATRO) and the European Research Group on Periodontology (ERGOPerio).

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