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REVIEW ARTICLE

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Orthodontic management of uneven gingival margins in patients with healthy or reduced periodontium to improve smile aesthetics

Conchita Martin[1,2] | Spyridon N. Papageorgiou[3] | Oscar Gonzalez-Martin[4,5] | Mariano Sanz[5,6]

[1]Section of Orthodontics, Department of Dental Clinical Specialties, Complutense University of Madrid, Madrid, Spain

[2]BIOCRAN (Craniofacial Biology: Orthodontics and Dentofacial Orthopedics) Research Group, Complutense University of Madrid, Madrid, Spain

[3]Clinic of Orthodontics and Pediatric Dentistry, Center for Dental Medicine, University of Zurich, Zurich, Switzerland

[4]Department of Restorative Dentistry and Biomaterials Sciences, Harvard School of Dental Medicine, Boston, USA

[5]Section of Periodontics, Department of Dental Clinical Specialties, Complutense University of Madrid, Madrid, Spain

[6]ETEP (Etiology and Therapy of Periodontal and Peri-implant Diseases) Research Group, Complutense University of Madrid, Madrid, Spain

Correspondence
Mariano Sanz, Department of Dental Clinical Specialties, Faculty of Dentistry, Plaza Ramón y Cajal, sn, 28040 Madrid, Spain.
Email: marsan@ucm.es

Abstract

Uneven gingival margins may cause visible asymmetries during smiling and may reflect alterations in the tooth shape and morphology, particularly in cases requiring restorative procedures. Despite being perceived as a minor health condition, presence of uneven gingival margins usually impacts the smile aesthetics and could affect the individual's appearance, self-esteem, and overall quality of life, especially in subjects with a high smile line. Uneven gingival margins may result from different causes, which makes an accurate diagnosis fundamental for its treatment planning. Orthodontic treatment often serves as a conservative approach for leveling these margins, by achieving the most appropriate tooth position. This article reviews the rationale, differential diagnosis, and clinical management of uneven gingival margins using orthodontic tooth movements, providing insights for orthodontists, periodontists, and restorative dentists on the interdisciplinary care needed to correct this condition, and hence, to improve the subject's smile aesthetics.

1 | INTRODUCTION

The presence of uneven gingival margins is characterized by irregularities or asymmetries in the contour of the gingival line, which may create not only a visible asymmetry when smiling but could also significantly affect the appearance of the shape and morphology of the teeth, particularly in cases where restorative procedures are necessary. Although an uneven gingival margin may seem like a minor health condition, its significance in smile aesthetics should not be underestimated, as it can significantly impact an individual's appearance, self-esteem, and overall quality of life.[1–4] These irregularities are therefore clinically relevant, particularly in the visible aspect of the dentition, due to the high prevalence of gingival visibility during natural and forced smiles,[5] and especially in the upper anterior maxilla of patients with a high smile line.[6]

The diagnosis of this condition must be considered within the context of the harmony between the teeth and gingival tissues, hence considering the periodontal and overall oral health, which are also highly relevant when considering an aesthetically pleasing smile. Although the aesthetic analysis should be contextualized within the psychological and cultural background of the patient, there are objective criteria that enable the dentist not only to diagnose the existing deficiencies but also to provide guidance for a corrective and restorative treatment plan. Magne and Belser[7] published a checklist of 14 objective criteria to guide treatment planning, including both pink and white aesthetics. Among the pink aesthetic criteria, gingival health, presence of interdental papilla, zenith of the gingival seam, balance of the gingival trigone, and smile symmetry were proposed as relevant aspects for determining the aesthetic outcome. This desired ideal harmony between white and pink aesthetics, however, may be challenging to achieve, or may not always be attainable, or not even be desirable, when seeking the ideal aesthetic outcome for a specific patient.

Within the context of orthodontic treatment, achieving gingival symmetry and margin stability is one the key principles for a successful aesthetic outcome. Orthodontic treatment approaches such as transverse arch development or alignment/leveling of the anterior region often involve rotation and extrusive/intrusive tooth movements to improve tooth positioning within the dental arch. These typically result in changes in the buccolingual tooth inclination,[8] which may influence the position of the gingival margin, its thickness and the width of keratinized gingiva.[9] Understanding how orthodontic interventions might impact the health and position of gingival tissues in the context of an intact or reduced healthy periodontium is, therefore, essential for achieving optimal treatment outcomes and enhancing the overall aesthetics of the smile. However, the subjective nature of the concept of aesthetics should be emphasized, as it is usually perceived differently by the patient and by the different specialists.[10]

Uneven gingival margins may be the consequence of either a more coronal position of the gingival margin relative to the margins of the adjacent teeth or, on the contrary, a more apical position of the gingival margin relative to the adjacent teeth. The differential diagnosis of uneven gingival margins, therefore, becomes very relevant, since various inflammatory, developmental, or traumatic processes may lead to this condition, and its treatment plan will often depend on the accurate identification of the causative factor. Regardless of the periodontal or restorative treatment plan used to restore the gingival margin position, since this position depends (at least to some degree) on the tooth position, orthodontic treatment is usually the most conservative first line intervention for leveling these margins (Figure 1). However, there is still lack of adequate knowledge on the predictability of orthodontic treatment to achieve the ideal position of the gingival margins and hence, there is a need for well-designed clinical studies to improve this knowledge. This article aims to review the rationale, differential diagnosis and clinical management of uneven gingival margins using orthodontic tooth movements. It seeks to provide orthodontists, periodontists, and restorative dentists with relevant insights into the comprehensive care of these patients seeking to improve their smile aesthetics.

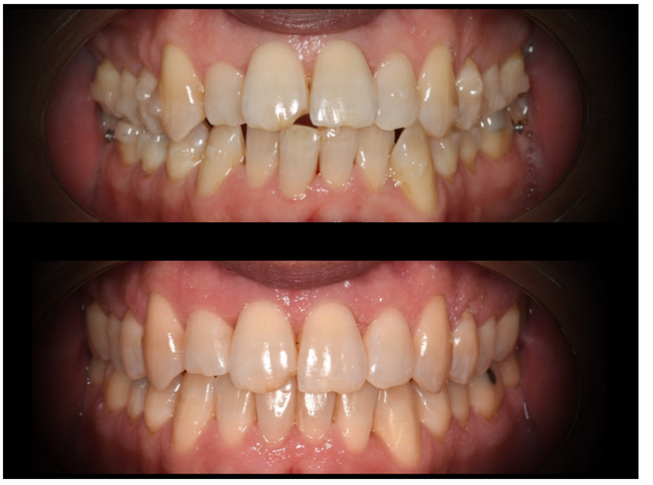

FIGURE 1 Patient with tooth crowding and minor alterations of the gingival margins. After orthodontic treatment, teeth are aligned with even gingival margins enhancing the patient's smile aesthetics.

2 | ETIOLOGY

The etiology of uneven gingival margins may include developmental, inflammatory, traumatic, and iatrogenic causes, such as altered passive eruption, dental malposition, tooth attrition, compensatory dental overeruption, gingival recession, gingival enlargement, and other mucogingival conditions. The identification and treatment of these conditions is fundamental for an appropriate management of the uneven gingival margins.

Genetic factors may affect the overall gingival genotype and tooth morphology, resulting in variations in tissue thickness and contour.[11] In individuals with long triangular-shaped anatomical crowns and thin gingival tissues, the smile may exhibit a thin-scalloped phenotype, characterized by knife-edge gingival margins and pronounced gingival scalloping. Conversely, subjects with thick gingival tissues and rectangular short crowns may display a thick-flat phenotype, characterized by thick gingival margins and minimal gingival scalloping (Figure 2). These phenotypic variations can significantly influence the final position and shape of the gingival margins after reconstructive dental and periodontal treatments, which often requires orthodontic correction for achieving a final leveling and adequate positioning of the gingival margins. Additionally, susceptibility to gingival inflammation is genetically determined[12] and, therefore, a precise diagnosis and personalized approach to the required periodontal therapeutic and preventive strategies is needed, since the recommended reconstructive and orthodontic interventions aimed to correct the uneven gingival margins can only be successful in presence of gingival and periodontal health.

Trauma-related factors, such as chronic mechanical trauma due to excessive toothbrushing or lip piercings, can lead to loss of periodontal attachment and subsequent localized gingival recessions, with consequent alterations in the position of the gingival margin. These alterations may pertain to a single tooth or to multiple adjacent teeth (Figure 3). Fractures/wear of incisal edges of anterior

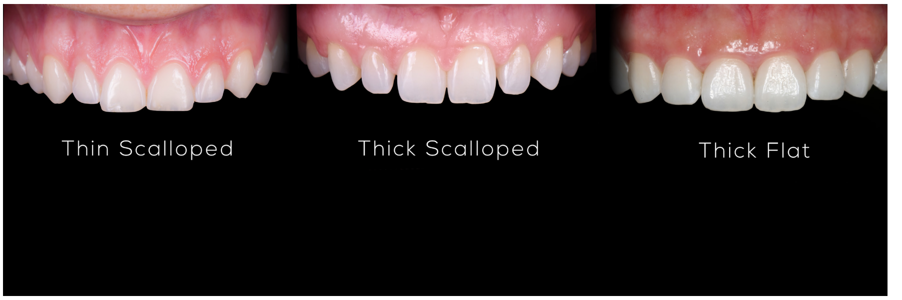

FIGURE 2 Thin-scalloped, thick scalloped, and thick-flat phenotype are the most common clinical variations that influence the final position and shape of the gingival margins after reconstructive dental and periodontal treatments.

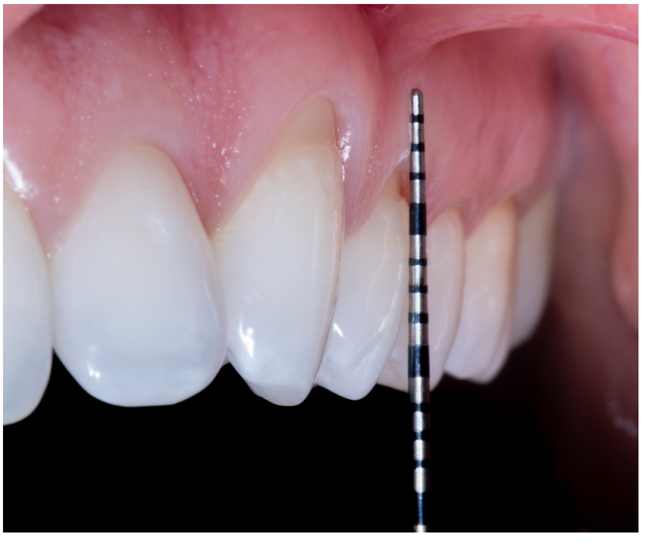

FIGURE 3 Trauma-related factors, such as chronic mechanical trauma due to excessive toothbrushing or lip piercings, can induce loss of periodontal attachment, leading to localized gingival recessions, with consequent alterations in the position of the gingival margin. These alterations may be associated with a single tooth or with multiple adjacent teeth (Courtesy of Dr. Avila-Ortiz).

teeth can also result in compensatory dental eruption and subsequent alterations in gingival margin contour (Figure 4).

Iatrogenic factors, mainly associated to orthodontic tooth movement and restorative procedures, may also result in uneven gingival margins, primarily due to gingival recessions. Specific orthodontic tooth movements, especially those moving teeth outside the bony envelope, such as uncontrolled tooth proclination, unfavorable root or crown torquing, uncontrolled transverse arch expansion, or inappropriate bracket placement, might lead to periodontal attachment loss and localized gingival recessions.[8,13] Similarly, poorly executed restorative treatments, such as ill-fitting crowns or over-contoured restorations, may disrupt the natural gingival architecture and compromise aesthetics by altering the gingival margin position. These localized gingival recessions must be corrected with the use of periodontal plastic reconstructive surgeries, using different combinations of flaps and grafts, which have shown a high degree of predictability in covering the exposed root.[14] However, achieving even gingival margins may often require further orthodontic correction.

Developmental anomalies, including altered passive eruption,[15,16] tooth impaction,[17,18] or aberrations in tooth eruption patterns,[19,20] may also contribute to irregular gingival contours and marginal discrepancies. Altered passive eruption usually affects young patients presenting with intact anterior incisal edges and undesirable crown width/height dimensions. Depending on the dimension of the keratinized tissues around the affected teeth and the position of the cemento-enamel junction (CEJ) in relation to the alveolar bone crest, altered passive eruption has been classified as Type I/Type II, with subgroups A and B.[21] Once the type/subtype of altered passive eruption has been determined, various periodontal surgical treatment plans (such as apically positioned flaps and gingivectomies, with or without bone remodeling) can be used to restore the clinical crown to its desired dimension. However, the final leveling and position of the gingival margins after these surgical interventions are not always stable and might require further orthodontic correction.

Specific types of malocclusions, such as dental crowding and misalignment,[22] frequently result in teeth erupting in a more vestibular position, which may lead to decreased gingival thickness and keratinized gingival width with subsequent gingival recession. Conversely, teeth erupting in a lingual position often lead to crowding and the presence of enlarged gingival thickness/width of keratinized gingiva.[23] Moreover, traumatic occlusal contacts have also been implicated in uneven tooth wear, resulting in compensatory overeruption of affected teeth and a subsequent coronal movement of the gingival margin, leading to irregular gingival margins. Similarly, parafunctional habits such as bruxism may also result in occlusal tooth wear, compensatory tooth eruption, and uneven gingival margins,[24] particularly in adult patients. In these clinical situations, orthodontic treatment becomes the treatment of choice not only to correct the malocclusion and restore the adequate tooth position, but also to level the gingival margins.

3 | DIAGNOSIS

In healthy conditions, the gingival tissues adhere closely to the underlying tissues, sealing the tooth attachment apparatus from the oral environment. This attachment comprises an epithelial component, known as the epithelial attachment, where the junctional epithelium organically adheres to the enamel through hemidesmosomes, and a connective tissue attachment, where the gingival fibers attach perpendicularly to the cementum just below the CEJ. This space, termed "supracrestal tissue height" is defined as the distance from the gingival margin to the bone crest, in which a minimum space for the gingival fiber attachment must always be preserved to maintain gingival tissue

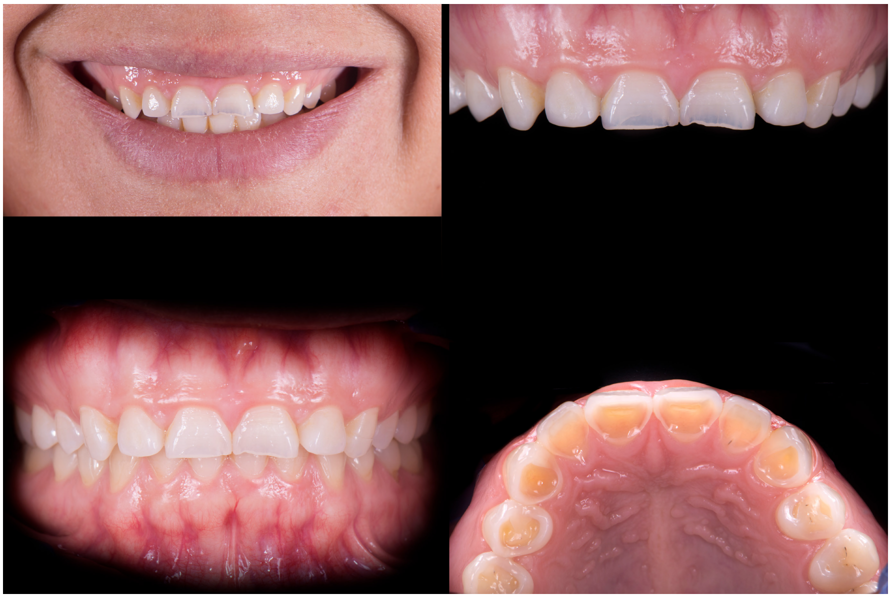

FIGURE 4 Fractures/wear of incisal edges of anterior teeth can also result in compensatory dental eruption and alterations in gingival contour.

health.[25] This structural organization is critical in the protection of the periodontium since it allows the local immune system to adequately respond to the highly contaminated oral environment. At the same time, the attached gingiva serves as a physical barrier, shielding the periodontium and underlying bone from all the physical and chemical noxa originating from the oral cavity.

Within this general framework, the shape of the gingival architecture can also be influenced by other factors, such as tooth position, the periodontal biotype, the tooth morphology and presence of noncarious cervical lesions, which may alter the configuration and position of the CEJ.[26] For a harmonious smile in the anterior maxilla, the gingival margins of the central incisors should align horizontally and be at the same level as the gingival margins of the canines, with the position of the lateral incisors' margins being slightly more coronal. However, not only is this ideal gingival outline and its symmetry relevant to smile aesthetics, but also the contours of the gingival margins in relation to the position of the CEJ, the size and shape of the gingival papilla filling the interdental space, and the presence of an adequate apico-coronal width (height) of the gingiva.[27,28] Although there is evidence that the integrity of the periodontium can be maintained in areas with a minimal zone of attached gingiva, its buccolingual thickness (thin vs thick phenotype) may be a significant predisposing factor of the final position of the gingival margins. In the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions,[29] this concept of "periodontal phenotype" was defined, encompassing the three-dimensional periodontal tissue volume, which includes the gingival thickness, the keratinized tissue width, and the bone morphotype. When diagnosing at the level of a single tooth/site, the term "gingival phenotype" should be used instead of the term "biotype," since the gingival thickness and position are determined not only by the predefined biotype but also by the actual tooth position. In sites with buccally positioned teeth, a thick periodontal biotype may be associated with a thin phenotype at this site, which indicates that the gingival phenotype should be diagnosed at the level of each tooth.

Clinically, the current gold standard for the measurement of gingival thickness remains transgingival probing,[30] although it is invasive and requires application of local anesthesia. To avoid this morbidity, an alternative clinical method involves evaluating the translucency of a color probe inside the gingival sulcus. Clinical studies have shown a correlation between this translucency and a gingival thickness of ≤1 mm.[31] In fact, in the lower incisors, the gingiva becomes nontransparent at a thickness of approximately 0.8 mm.[32] These results have led to the proposal of a gingival phenotype classification as thin (<1 mm) and thick (>1 mm) depending on the translucency of a colored periodontal probe.[33] In clinical research, other more sophisticated measurement methods such as the use of ultrasonic devices[34] or intra-oral dental scanners can also be used for the diagnosis of unaesthetic gingival countours.[28,35,36] Although ultrasonic measurement methods have shown comparable outcomes to direct clinical assessments in the anterior area, their accuracy in the posterior area seems limited.[30] With the advent of new digital and ultrasonic technologies, more accurate and reproducible noninvasive evaluation of the gingival architecture might soon be possible.

Similarly, different investigations have demonstrated a positive correlation between the buccal gingival thickness measured with cone beam computed tomography and the gingival width measured by transgingival probing.[37] In fact, a recent systematic review compared cone beam computed tomography ultrasound, and direct transgingival probing,[38] concluding that, compared to direct probing, cone beam computed tomography was a relatively reliable method for measuring gingival thickness in both the anterior and posterior areas. However, the use of ionizing methods should be avoided if similar results can be obtained with nonionizing diagnostic methods.[39]

Uneven gingival margins may be present in periodontally healthy patients as well as in periodontitis patients. In fact, one of the most frequent sequelae of periodontal therapy is the presence of long teeth with a flat gingival contour and loss of interdental papilla. However, as stated before, the correction of uneven gingival margins can only be carried out once the periodontal tissues are healthy and, in these patients with a healthy but reduced periodontium, the rehabilitation of proper clinical crowns and gingival margins often requires complex interdisciplinary treatments, requiring well-coordinated periodontal, orthodontic, and restorative interdisciplinary treatment plans to ensure proper tooth position and restoration of contact points and interocclusal contacts. The recently published Clinical Practice Guideline for the Treatment of Stage IV type 2 periodontitis patients provides clear recommendations for the comprehensive treatment of these patients.[40]

When gingival margin discrepancies are present, it is essential to determine the appropriate treatment plan, comprising of either orthodontic tooth movements alone to reposition the gingival margins, or combination with surgical interventions, with or without associated restorative treatments.

4 | ORTHODONTIC TOOTH MOVEMENT AND EFFECTS ON GINGIVAL MARGINS

4.1 | Effects of orthodontic tooth movement on periodontal tissues of periodontally healthy patients

Orthodontic tooth movement involves an aseptic inflammation process, where the tooth moves through the alveolar bone, followed by the remodeling of the surrounding hard and soft tissues. There is ample evidence that with an adequate control of periodontal inflammation through effective oral hygiene practices, orthodontic tooth movement has a transient effect on periodontal tissues,[41,42] and does not result in clinically significant permanent tissue damage.[43] Transient orthodontic treatment-related effects may include increases in clinical plaque/bleeding indices,[44] slight deepening of the gingival sulcus (average 0.23 mm),[44] marginal bone loss (average 0.13 mm),[44] clinical attachment levels (average 0.11 mm),[45] and quantitative or qualitative changes in the oral and subgingival microbiota.[46,47] In fact, these changes in the microbial composition due to orthodontic treatment[48,49] are thought to be influenced by the biofilm-retentive nature of orthodontic appliances, which usually reverts to normal levels after treatment.[50] Additionally, in some patients, gingival hyperplastic changes[51] during the orthodontic treatment may lead to an environment conducive to bacterial dysbiosis and chronic inflammation that should be controlled with adequate periodontal treatment strategies.

4.2 | Gingival response to orthodontic treatment in general

Predicting the impact of various orthodontic tooth movements on gingival margins can be challenging due to the potential role of factors such as age, periodontal phenotype, and periodontal health status. Certain types of orthodontic tooth movements, however, are associated with specific gingival changes. For example, in the vertical direction, tooth intrusion is linked to a corresponding apical displacement of the gingival margin, although this effect depends on the periodontal status of the patient. Similarly, extrusive tooth movements are more frequently associated with a corresponding coronal migration of the gingival margin. Extensive labial tooth movements are often associated with an apical migration of the gingival margin, whereas a coronal migration of the gingival margin might more often be associated with lingual uprighting of a tooth's crown. In all these situations, however, the three-dimensional positioning of the tooth's root usually deviates considerably from the corresponding movement or position of the tooth's crown.

Orthodontic treatment with fixed appliances in general has been associated with an overall increased risk of developing gingival recessions. Four case–control studies compared the prevalence of gingival recession between orthodontically treated patients and control groups over similar observation periods.[52–55] Meta-analysis of these studies performed for this paper (using a restricted maximum likelihood random-effects model) indicated that, approximately 5 years posttreatment (or the equivalent observation period for untreated control patients), orthodontically treated patients were significantly more likely to exhibit at least one gingival recession compared to control subjects (odds ratio 2.74; 95% confidence interval [CI] 1.78–4.31; $p < 0.001$; heterogeneity I^2 43%). However, it is important to highlight that gingival recession is a complex multifactorial phenomenon present frequently in absence of orthodontic treatment and seems to be affected by different influencing factors, such as increased patient age, tooth wear, smoking, trauma/parafunction, pregnancy, and presence of iatrogenic elements, such as piercings.[56–59] From a periodontal perspective, a thin gingival phenotype, previous gingival recessions, width of keratinized gingiva, facial gingival margin thickness, and biofilm accumulation on the labial tooth aspect have also been associated with an increased risk of gingival recessions.[53,59] From an orthodontic standpoint, craniofacial morphology,[60] symphysis anatomy, crowding, ectopic eruption, posterior crossbite, incisor proclination, and orthodontic tooth movement outside the alveolar bony envelope have also been linked to an increased risk of gingival recession after orthodontic treatment.[57,59,61–63] Apical migration of the gingival margin occurs more frequently, when the lower intercanine width is increased or decreased during orthodontic treatment (34%), compared to when it is left unaltered (21%). On the other hand, coronal gingival margin migration is more common when the lower intercanine width remains unchanged during treatment (15%), as opposed to cases where it decreases or increases (3%). Closs et al.[63] reported that migration of the gingival margin occurred in 37% of the cases following orthodontic treatment with fixed appliances. Lo Russo et al.[64] reported no significant correlation between the sagital or vertical movements of the crown and the displacement of the gingival margin, but observed that proclination and extrusion movements were associated with changes in the position of the gingival margin.

In a long-term evaluation of adolescent and adult patients 2 and 10 years after orthodontic treatment, Theytaz and colleagues[65,66] found that apical displacement of the gingival margin and gingival contour alterations in the upper central incisors associated with orthodontic treatment were more prevalent during adolescence than in adulthood. Additionally, they found that there was an association of gingival displacement during tooth eruption and increase in lower facial height. Rasperini et al.[31] reported that the effect of orthodontic treatment with fixed appliances on the keratinized gingival width was heavily dependent on both the patient's periodontal phenotype (categorized as thin, medium, thick, and very thick) and on the orthodontic tooth movement performed. Whereas keratinized gingival width reductions were seen in patients with thinner periodontal phenotype, in patients with thicker phenotype, the gingival alterations were minor or with a slight tendency to increase the keratinized gingival width during treatment.[23] Furthermore, whereas pure alignment of the teeth seemed to have no effect on keratinized gingival width, proclination was associated with decreased and retroclination with increased keratinized gingival width. Alkan et al.[9] reported that keratinized gingival width was on average only slightly affected by orthodontic treatment, with significant decreases seen only for the upper lateral incisors and especially when these were protruded.

4.3 | Gingival margins' alignment after orthodontic alignment of displaced teeth

In the transition from deciduous to early mixed and permanent dentition, frequent changes in the gingival margins usually occur and are associated with the eruption process. The final establishment of the supra-crestal tissues, which occurs through passive eruption and apical migration of the attachment, is not fully completed until the end of adolescence.[67]

In teeth with crowding or ectopic eruption, the gingival margins of these displaced teeth are usually misaligned, which can be aggravated in presence of malocclusions, frequently resulting in uneven gingival margins and an unpleasant aesthetic appearance. Orthodontic treatment during the mixed dentition phase in growing children has been associated with improvements in the position of the gingival margins leading to more harmonious smiles. A study by Harrison et al.[68] assessed the gingival margins of children with anterior crossbite of lower central permanent incisors, associated with an excessive labial inclination, before and after orthodontic correction. They found that 42% of anterior crossbites were associated with a gingival margin alteration of at least 1.0 mm (compared to the incisor not in crossbite), and that gingival margin discrepancies were more often seen when then central incisor was in crossbite compared to the lateral incisor (55% vs 25%). After treatment with removable appliances in the upper arch, in most cases, discrepancies in the position of the gingival margin were resolved after the orthodontic correction of the anterior crossbite.

Lione et al.[69] reported that early treatment for crowding in children in the early mixed dentition with transverse arch development using sequential aligners was associated with changes in the gingival margin position leading to more harmonious smiles. Maxillary expansion usually reduces the gingival margin heights in deciduous canines, with a reduction in gingival margin height of 0.12 mm for each degree of vestibular inclination. At the level of upper incisors, a mean reduction of 0.43 mm was detected after a slight buccal inclination to correct anterior crowding. Saini et al.[70] assessed orthodontically treated patients and found that, after treatment, in the vast majority of the patients (93%; 74/80), the position of the gingival margin of the anterior teeth relative to each other improved after treatment and only a few patients (3%; 2/80) showed worse or no change (5%; 4/80) in aesthetic outcomes. Similarly, Antanavičienė et al.[71] evaluated retrospectively the effect of orthodontic treatment in patients with at least one gingival recession and reported that orthodontic treatment improved the recessions by a mean 0.51 mm, while in 22% of the cases, the recession was completely resolved, although this beneficial effect was more limited in patients with Class III malocclusion and open bite.

In clinical situations where orthodontic tooth movements result in gingival enlargement, mainly in the anterior dentition, the redundant gingival tissue can be excised to avoid plaque accumulation and gingival inflammation, and to allow for better oral hygiene practices. These interventions (gingivectomies) should be performed during orthodontic treatment if inflammatory changes prevent plaque control, or alternatively, following debonding and active orthodontic treatment to achieve more stable and well-aligned gingival margins. However, in young patients (below 16 years), these surgical interventions should be avoided since gingival remodeling and maturation is still taking place, and the gingival margin levels are not yet at their final stable position.

4.4 | Gingival response to orthodontic tooth intrusion

Orthodontic tooth intrusion requires the application of a constant apical force of small magnitude. The reaction of healthy periodontal tissues to orthodontic tooth intrusion have been investigated both in animal and human studies. Animal studies have shown that the application of continuous and low intrusive forces with fixed appliances have minor effects on a healthy periodontium and lead to minimum marginal bone loss.[72–74] This is associated with a movement in the apical direction of the sulcus base and the mucogingival junction, with an increase in sulcular depth, a decrease in the clinical crown length, and as a result, a re-seating of the junctional epithelium at the cemento-enamel junction.[74] Two clinical studies in humans have reported the gingival response to intrusion of anterior teeth.[75,76] Erkan et al.[75] found that after intruding the mandibular incisors by 2.6 mm, the gingival margin moved apically by 2.1 mm (79% of the intrusion), while the mucogingival junction moved apically 1.6 mm

(62% of the intrusion). Additionally, the incisors' clinical crown was shortened by 0.6 mm (24% of the intrusion), while the widths of the attached/keratinized gingiva were only slightly affected (−0.4 mm and −0.3 mm, respectively). However, tooth movements purely in an apical direction are seldom produced and some degree of proclination is usually observed. In the two existing studies, this proclination amounted to about 4.2° after an intrusion of 2.6 mm of either the upper or the lower incisors. The response of the hard tissues to orthodontic intrusion in the absence of inflammation is minimal and corresponds to the average response to any kind of orthodontic tooth movement. It seems therefore that isolated tooth intrusion can be used to correct the gingival margin of overerupted teeth, but the amount of needed intrusion is larger than the amount of gingival discrepancy, since the gingival margins do not respond on a 1:1 ratio. Additionally, since a shortening of the clinical crown (of about 24% of the intruded amount) can be seen after intrusion,[75] over-intrusion of the target tooth might be needed, so that the resulting reduced clinical crown can be subsequently restored surgically to its proper clinical length.

Bellamy et al.[77] reported that with an average intrusion of 2.2–2.4 mm, a minimal reduction in the alveolar bone level of about 0.2–0.4 mm was observed, consistent with the average response to orthodontic treatment.[44] At the same time, an average apical root resorption of about 1.3–1.8 mm was reported,[77,78] which is, however, twice the average root resorption of about 0.8 mm typically associated with orthodontic treatment.[79] Interestingly, this level of root resorption does not appear to be correlated with the amount of tooth intrusion.[78,80] Orthodontic tooth intrusion has traditionally been associated with an increased apical root resorption[81] due to the concentration of high compression stresses in the relatively small apical area of the periodontium,[82] damaging the vascular supply and resulting in hyalinized tissue periapically. However, while some studies suggest that higher forces are associated with increased root resorption,[83] others refute this claim.[84] Additionally, it seems prudent to keep the applied intrusive forces as low as possible, hoping that the reactive extrusive forces on the posterior tooth segment will be nullified by the occlusion. Overall, it seems that the response of periodontal tissues to orthodontic intrusion is minimal, although with a tendency toward increased apical root resorption, which should be explained to the patient beforehand (Figure 5).

4.5 | Gingival response to orthodontic tooth extrusion

Orthodontic tooth movement in an extrusive vertical direction can be used to move the periodontal tissues in the same direction. In fact, several studies have reported that with the application of slow extrusive forces (approximately 1 mm activation per month), the gingival margin follows the tooth movement. Kan et al.[85] reported that the position of the gingival margins of upper incisors followed in an incisal direction by 93% of the extruded tooth (4.27 mm by a 4.62 mm tooth extrusion). Also in upper incisors, a more rapid extrusion protocol (with weekly activation) reported almost a 1:1 response of the gingival margin (2.10 mm by a 2.11 mm extrusion).[86] However, in hopeless upper incisors, Amato et al.[87] reported that their forced extrusion was associated with a reduced displacement of the gingival margin (3.65 mm gingival margin displacement in relation with a 6.21 mm tooth

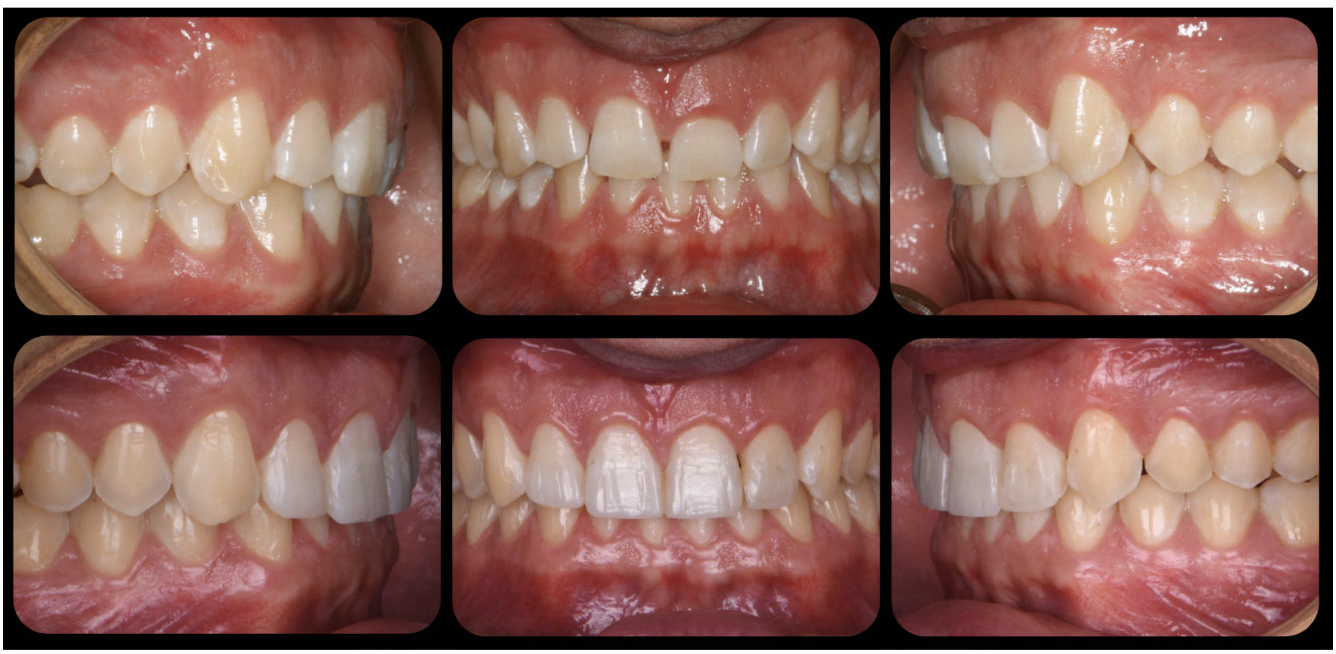

FIGURE 5 Clinical case of orthodontic intrusion of central incisor to level the cemento-enamel junction (CEJ) and gingival margin previously to restore the incisal edge.

extrusion; a 65% rate). In lower incisors, a gingival displacement rate of about 80% has been reported after tooth extrusion (a 2.56 mm gingival margin movement by a 3.20 mm tooth extrusion).[88] These results point out that a certain amount of gingival recession associated with the subsequent increase in clinical crown length is the usual consequence of the orthodontic extrusion, ranging from 1.02 mm (by a 3.20 mm extrusion in Pikdoken et al.[88]) to 1.84 mm (by a 6.21 mm extrusion in Amato et al.[87]). The width of the keratinized gingiva also appears to increase as a result of orthodontic tooth extrusion, but to a variable degree according to various studies, ranging between 27% and 90% of the extruded amount.[85,87,88] Contrasting evidence exists regarding whether the position of the mucogingival junction is affected by orthodontic tooth extrusion. Two studies reported changes by 33%–53% of the extruded amount,[87,88] while a third found no effect on the mucogingival junction.[85] Finally, the alveolar bone level seems to respond similarly to the application of extrusive forces, in a relatively consistent manner, ranging from 63% to 77% of the extruded amount.[85–87] Overall, the gingival margin seems to follow the coronal movement of the tooth, although tooth over-extrusion might be needed to counteract the potential recession, and subsequent restorative treatment might be needed to restore the clinical crown to its desired length.

The combination of orthodontic tooth extrusion with circumferential supracrestal fiberotomy (CSF) has been recommended to increase the length of the clinical crown without affecting the position of the gingival margins. Both Carvalho et al.[86] and Faramarzi et al.[89] reported that weekly activation of extrusive forces combined with weekly CSF led to increased tooth extrusion in comparison with extrusive forces without CSF, while both the gingival margin and the alveolar bone levels remained practically unchanged. These results suggest that CSF may not be indicated in cases with discrepancies of the gingival margins but should be used in cases where crown lengthening is indicated.

Gonzalez-Martin et al.[90] have proposed several indications for orthodontic forced extrusion: treatment of vertical/angular periodontal bone defects to reduce their infrabony component, implant site development in preparation for dental implant placement in presence of hopeless teeth, and modifications of the soft tissue envelope to correct papillary deficiencies of inadequate gingival zenith positions. In all these indications, the gingival margin will be displaced, but these authors propose the application of different forces, the use of CSF, and use of intermediate tooth stabilization (ITS) periods to modulate the degree of the gingival margin coronal displacement (see Table 1). ITS periods refer to intervals during orthodontic treatment where the teeth are temporarily stabilized to allow for adaptation and consolidation of the tooth movement before further adjustments are made. This is commonly achieved by keeping the archwires passive, typically for a period of 4–6 weeks, before the next activation.

4.5.1 | Orthodontic extrusion with CSF and without ITS

In cases with high aesthetic demands requiring an increase of the clinical crown for aesthetic purposes, the use of continuous eruptive forces with frequent severance of periodontal fibers (CSF), but without ITS periods, has been recommended as an alternative to surgical crown lengthening. This protocol achieves the exposure of

TABLE 1 Aim, biologic rationale, clinical protocol, and main indications of different orthodontic forced eruption modalities (adapted from Gonzalez-Martin et al.[90]).

	Aim	Biologic rationale	Clinical protocol	Indication(s)
OFE with CSF and without ITS	Tooth extrusion with no modification of periodontal tissues	Uninterrupted tooth extrusion avoiding elongation of periodontal fibers to prevent tension on the gingiva and crestal bone	Forced extrusion with periodic severance of supracrestal periodontal fibers and root planing, and without intermediate tooth stabilization	Expose subgingival/subcrestal tooth structure to facilitate restorative therapy
OFE without CSF or ITS	Tooth extrusion with traction of gingival tissues and unpredictable alveolar bone changes	Uninterrupted rapid tooth extrusion with intentional elongation of periodontal fibers *Note*: This approach may cause sulcular epithelium eversion and a subsequent recession defect	Forced extrusion with no fiberotomy and without intermediate tooth stabilization *Note*: A longer stabilization period upon completion of tooth movement is usually required with this approach	Modification of the soft tissue envelope Implant site development
OFE without CSF and with ITS	Tooth extrusion with traction of both gingival tissues and alveolar bone	Elongation of periodontal fibers with interrupted tooth extrusion to allow for reorganization of the supracrestal gingival fibers and bone apposition. *Note*: This approach rarely causes sulcular epithelium eversion and a subsequent recession defect	Forced extrusion with no fiberotomy and with periods of intermediate tooth stabilization	Management of impacted teeth Treatment of periodontal infrabony defects Modification of the soft tissue envelope Implant site development

Abbreviations: CSF, circumferential supracrestal fiberotomy; ITS, intermediate stabilization periods; OFE, orthodontic forced extrusion.

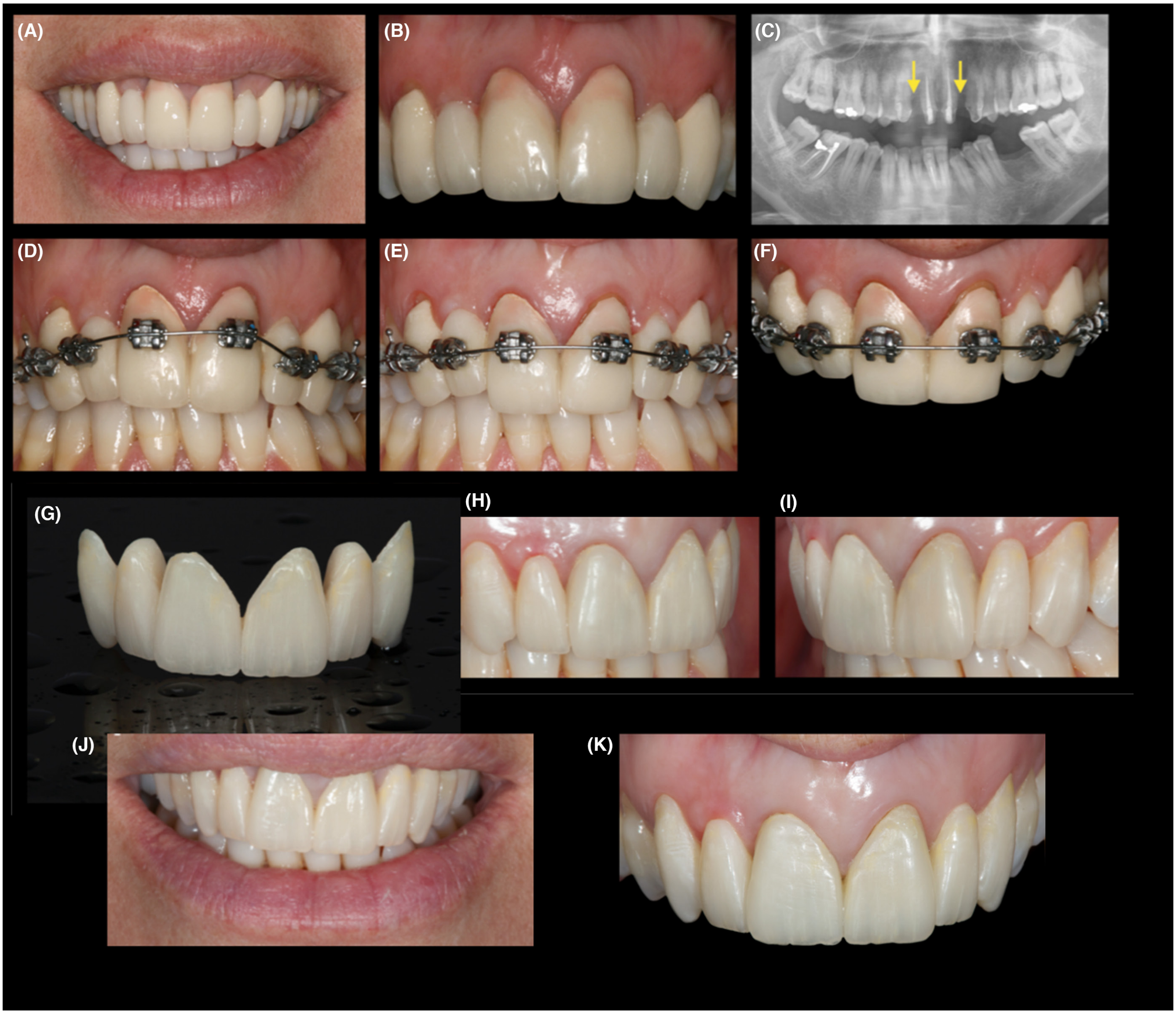

FIGURE 6 Application of orthodontic forced eruption with no circumferential supracrestal fiberotomy (CSF) or intermediate stabilization periods (ITS) to optimize the a esthetic outcome for the replacement of two bilateral, 3-unit, tooth-supported fixed dental prostheses in the anterior maxilla. (A, B) Initial clinical presentation. Note the agenesia of both lateral incisors, the mid-buccal recession on both central incisors and the poor a esthetics of the existing restoration. (C) Orthopantomograph. Note the root canal treatment of the central incisors and loss of interproximal bone on the distal aspect of both teeth. (D, E) Orthodontic forced eruption was done for 2 months. (F) Initiation of the stabilization process, which lasted 3 months. Note the marginal "red patch," which is indicative of eversion of the sulcus. (G) Provisional restoration. (H, I) Final insertion of the provisional restoration. (J, K) 6 years follow-up with the final restoration.

subgingival or subcrestal tooth structure without simultaneous displacement of supporting bone and soft tissues.

4.5.2 | Orthodontic extrusion without CSF and ITS

In cases of desired implant site development, the preservation and stretching of the supracrestal soft tissues can be achieved by continuous coronal movement without CSF and ITS. With this protocol, the supracrestal fiber reorganization during active tooth movement will not occur and the tooth displacement will intentionally elongate and stretch these fibers, moving coronally the alveolar crest and the whole soft tissue envelope. Once the tooth and bone movement have been achieved, a longer stabilization period and proper oral hygiene control can then allow the reestablishment of the sulcus and superficial keratinization (Figure 6).

4.5.3 | Orthodontic extrusion with ITS but without CSF

In presence of localized intrabony defects with a significant vertical component, uneven gingival margins and interproximal papillary defects, the application of light and continuous orthodontic forces with no CSF, but with intermediate tooth stabilization periods, can promote new bone apposition with reorganization of the supracrestal fibers. This protocol typically achieves tooth movement and simultaneous displacement of surrounding bone and tissue at a rate of 0.5–1 mm per month. However, treatment duration is primarily influenced by local anatomy and therapeutic goals (Figure 7).

4.6 | Uneven gingival margins in periodontitis patients

Patients with stage III–IV periodontitis, defined by severe attachment loss, often present pathologic tooth migration, characterized by mesial drifting of the posterior dentition and posterior bite collapse, flaring of the anterior maxillary teeth accompanied by extrusion and diastemas, and secondary occlusal trauma. These features impact the architecture of the gingival margins in different ways, leading to gingival asymmetries, flat gingival margins, and open gingival embrasures.

Once an appropriate periodontal therapy has been successfully concluded, the management of alterations in the gingival contours might necessitate controlled orthodontic tooth movements, either by intrusion or extrusion of one or more teeth, closure of diastemas, and uprighting of tilted teeth. These can effectively realign teeth within the dental arch, but often require additional restorative treatments, such as interproximal enamel reduction and restoration of dental contact points in a more apical position to eliminate or reduce black triangles, or more complex restorative procedures such as laminate or composite veneers to significantly improve the unaesthetic consequences of periodontitis and its treatment (Figure 8).

Although most studies evaluating the effects of orthodontic tooth movement in periodontitis patients have focused on assessing the changes in probing depth and clinical attachment levels,[91,92] few have specifically addressed changes related to the position of the gingival margins. These studies have typically focused on the effect of orthodontic tooth movements, such as intrusion or retraction of elongated/flared incisors on the anterior maxillary region, or conversely controlled tooth extrusion. The outcomes evaluated in conjunction with these orthodontic tooth movements include gingival recessions, the clinical crown length, and the height of the interdental papilla.

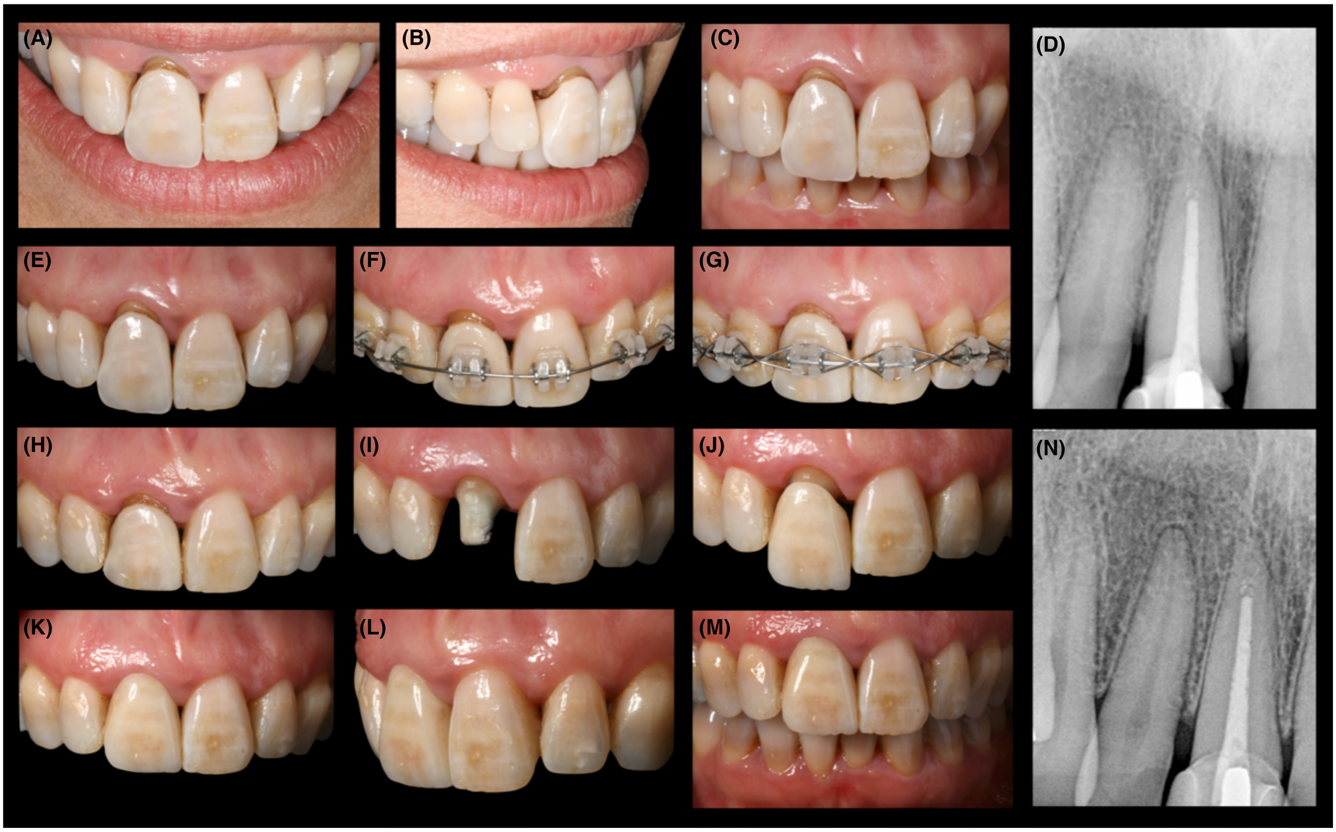

FIGURE 7 Modification of the position of the gingival zenith and interproximal tissues using orthodontic forced eruption with no circumferential supracrestal fiberotomy or intermediate stabilization periods to optimize the restorative outcome of a single tooth-supported ceramic crown. (A–C) Initial clinical presentation of right maxillary central incisor exhibiting mid-buccal recession and deficient of distal papilla. (D) Periapical radiograph showing incorrect crown fit and alveolar bone levels. (E) Frontal view of the anterior sextant prior to the initiation of treatment. (F) Aspect of the site after 3 months of forced eruption. (G, H) Tooth stabilization lasted 4 months. (I, J) Final crown preparation and try in. (K–M) Final result. Note the stability of the soft tissue. (N) Final periapical radiograph demonstrating correct fitting and stable interproximal bone level.

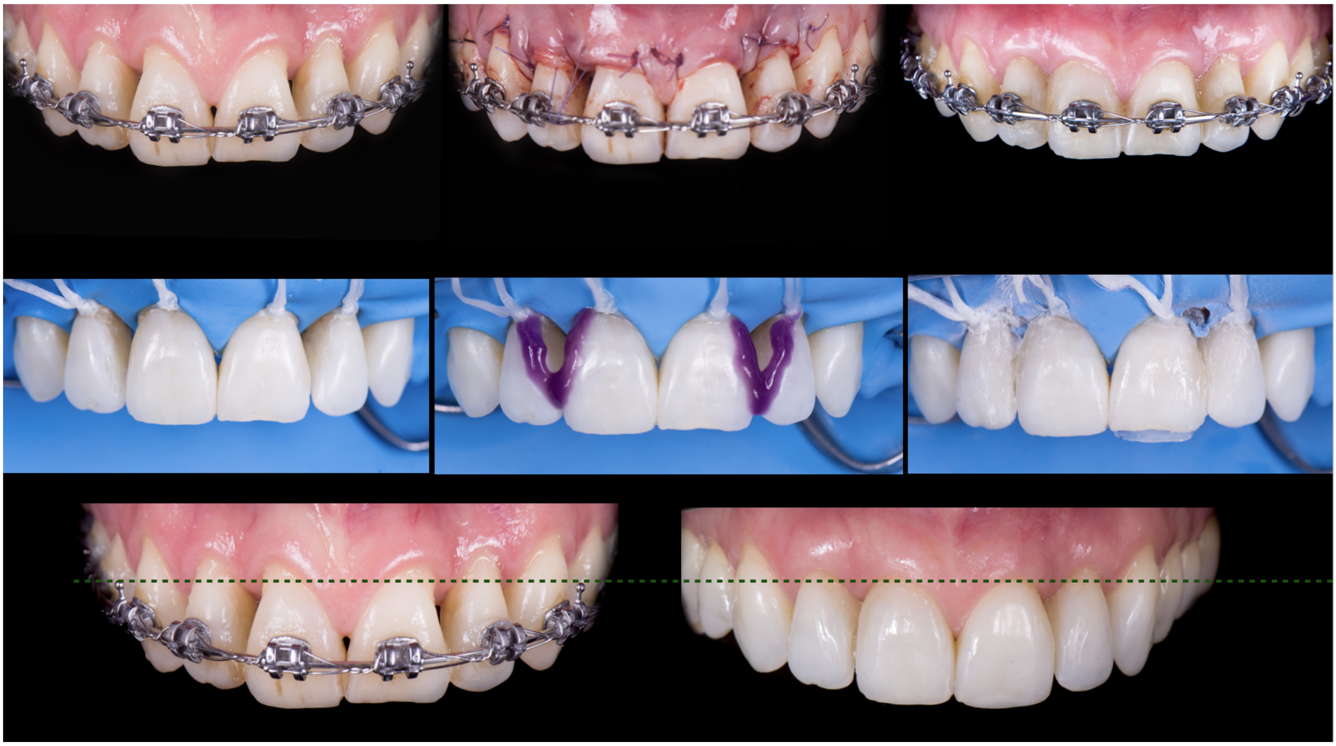

FIGURE 8 After an appropriate periodontal therapy, the management of these alterations in the gingival contours often involves controlled orthodontic movements, either by intrusion or extrusion of one or more teeth, closure of diastemas and uprighting of tilted teeth. These interventions can effectively realign teeth, and correct malpositions, but often require restorative treatments, such as interproximal enamel reduction and restoration of dental contact points in a more coronal position to eliminate or reduce black triangles, or more complex restorative procedures such as laminate or composite veneers to significantly improve the unaesthetic consequences of periodontitis and its treatment. In this particular case, after orthodontic alignment, a connective tissue graft was performed, followed by an embrasure closure by free-hand composite restorations in order to achieve the desired a esthetic result.

4.6.1 | Changes in the gingival margins after orthodontic intrusion

The effect of orthodontic intrusion on the changes in the gingival margin in patients with severely compromised periodontal condition has been reported in several clinical studies. While some studies reported no significant changes in gingival recessions,[93–95] others found significant improvements in the position of the gingival margin after orthodontic treatment.[96,97] Aimetti et al.[93] reported that these patients showed an increase in gingival recessions after the periodontal therapy, but the gingival margins remained stable both during orthodontic treatment and after a 10-year follow-up. Ghezzi et al.[94] treated flared incisors with guided tissue regeneration and orthodontic intrusion, reporting a minimal statistically nonsignificant reduction in gingival recession of −0.80 mm ($p=0.10$). Similarly, in a split-mouth randomized clinical trial[95] of 27 periodontally compromised patients treated with and without laser, no significant intragroup or intergroup differences were detected for gingival recession at any time point after orthodontic treatment. Conversely, in 28 periodontitis patients who underwent orthodontic intrusion 10 days after periodontal surgical therapy, the maxillary central incisors demonstrated an average intrusion of 1.95 mm, together with a statistically significant reduction in recession at both the buccal (mean: 0.96 mm; 95% CI: 0.72–1.20 mm; $p<0.001$) and mesial sites (mean: 1.71 mm; 95% CI: 1.35–2.07 mm; $p<0.001$). This treatment-induced reduction in recession was slightly larger in patients with thick biotype than in patients with thin biotype (1.17 mm vs 0.70 mm, respectively), but this was not formally statistically significant ($p=0.07$).[96,97] Carvalho et al.[98] compared the periodontal effects of orthodontic treatment between periodontitis patients and a periodontally healthy control group. While orthodontic treatment in periodontally healthy patients was associated with a minor increase in the number of sites with gingival recession, orthodontic treatment of periodontitis patients led to a reduction in the number of sites with recession (+0.40 vs −13.90 sites, respectively), which was statistically different between groups (difference − 14.30; 95% CI: -24.82 to −3.78 sites; $p=0.008$).

The effect of orthodontic intrusion on the clinical crown length of pathologically migrated teeth in patients with severely compromised periodontal condition has been assessed in several clinical studies. Cardaropoli et al.[99] evaluated the effect of intrusive orthodontic tooth movements on migrated maxillary central incisors in the presence of infrabony defects in severe periodontitis patients and reported significant reductions in clinical crown length. In a similar patient population, Melsen et al.[100] reported an overall minimal reduction in clinical crown length of 1.08 mm, even though these effects were very heterogeneous and ranged between an increase of 1.3mm to a reduction of 3.8mm. This reduction was most pronounced lingually with resulting marginal bone levels reducing the distance to the cemento-enamel junction in all but six cases.

This apical movement of the CEJ following intrusion is characteristic of flared teeth in periodontitis patients, since in nonperiodontitis patients, tooth intrusion typically maintains relatively constant alveolar bone levels in relation to the CEJ. This CEJ intrusion in periodontitis-affected dentitions may result in reduction of the dimensions of intrabony lesions, provided the affected roots have been thoroughly debrided, usually involving periodontal surgery before orthodontic treatment.[97,99–101]

The effect of orthodontic intrusion on the maxillary interdental papilla of pathologically migrated teeth in patients with severely compromised periodontal condition has been assessed in several clinical studies. Cardaropoli et al.[102] using the Nordland & Tarnow[103] index reported significant improvements in papilla presence index (mean: −0.93; 95% CI: −1.15 to −0.70; $p < 0.05$), with no statistically significant differences between patients with thin or thick periodontal biotypes (means: −0.94 and −0.90, respectively; $p = 0.88$). Ghezzi et al.[104] in patients with anteriorly migrated incisors with diastema, treated with guided tissue regeneration and orthodontic intrusion, found a statistically significant reduction in papilla presence index of −0.64 (95% CI: −1.07 to −0.21; $p = 0.007$). Kim et al.[105] reported changes in the vertical position of the interdental papilla following the approximation of anterior teeth in periodontitis patients with pathologic tooth migration, measuring the distance from the incisal margin to the tip of interdental papilla and found that it was reduced to a statistically significantly degree during treatment (difference: −1.72mm; 95% CI: −1.90 to −1.54mm; $p < 0.001$). The shape of the teeth had a statistically significant impact on the interdental papilla score (Pearson's coefficient 0.53); however, there was a very weak correlation with the changes in the interproximal alveolar crest level (Pearson's coefficient 0.07). The different outcomes related to gingival margins reported in these investigations may be due to the use of different evaluation methods, mainly by the use of different papilla indexes (Nordland & Tarnow[103] vs the papilla index score (PIS) by Jemt[106]).

4.6.2 | Changes in the gingival margins after orthodontic extrusion

As previously mentioned, Amato et al.[87] found that recession increased by 1.74mm (95% CI: 1.21–2.26mm; $p < 0.001$) when extruding hopeless teeth for implant site development. This effect was independent from the increase in height of the periodontal and bone levels achieved during the extrusive movement, although the effect in the gingival tissues was highly variable and was dependent on the existing probing depth. The coronal tooth movement was always accompanied by movement in the bone level, but the soft tissue margin only migrated coronally in absence of pockets.

Kwon et al.[107] studied the effect of slow forced eruption on the vertical levels of the interproximal bone and papilla height in patients with hopeless maxillary anterior teeth. Papilla height was measured as the distance from an acrylic stent to the mesial and distal peaks of the interproximal papilla before and after forced eruption. The mean interproximal papilla height demonstrated a statistically significant increase by 1.09mm (95% CI: 0.87–1.31mm; $p < 0.001$) after forced eruption, while this was significantly correlated with the changes in interproximal alveolar bone levels (coefficient 0.50). A finding that contrasts with the discrepancy between gingival and bone levels after intrusive movements reported by the same authors.[105]

4.6.3 | Orthodontic biomechanical considerations

To achieve predictable outcomes during intrusive and extrusive movements, it is important to consider several orthodontic biomechanical factors that will impact the tooth's response to the applied forces such as: the point of force application, the type of appliance (buccal or lingual fixed appliances) and archwire used[108]; the type of anchorage, whether dental or skeletal; the center of resistance of the tooth, which will shift apically as periodontal support decreases; and the resultant force moment generating a moment or torque, which is related to the combined effect of the applied force and the distance from the center of resistance. A precise control of this resultant force moment is essential for guiding tooth movement effectively and for minimizing the undesirable tipping and uncontrolled vertical movements.[109]

During vertical movements, such as intrusion or extrusion, periodontal fibers undergo oblique orientation and stretching as the root moves apically or coronally. It takes approximately 6months for the reorientation and adaptation of these fibers to the new position, therefore, during this period, there is a high risk of significant relapse, which highlights the importance of the maintenance and stabilization of the teeth in their new vertical position using the appropriate retention either by fixed retainers or by keeping the orthodontic appliances for a minimum of 6months. Some authors even advocate for a retention and stabilization period of no less than 1month for every month of active extrusion.[110]

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CONFLICT OF INTEREST STATEMENT

All the authors declare no conflict of interest related with the content of this manuscript.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Conchita Martin https://orcid.org/0000-0003-3997-6900
Spyridon N. Papageorgiou https://orcid.org/0000-0003-1968-3326
Oscar Gonzalez-Martin https://orcid.org/0000-0003-3957-4872
Mariano Sanz https://orcid.org/0000-0002-1287-6320

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