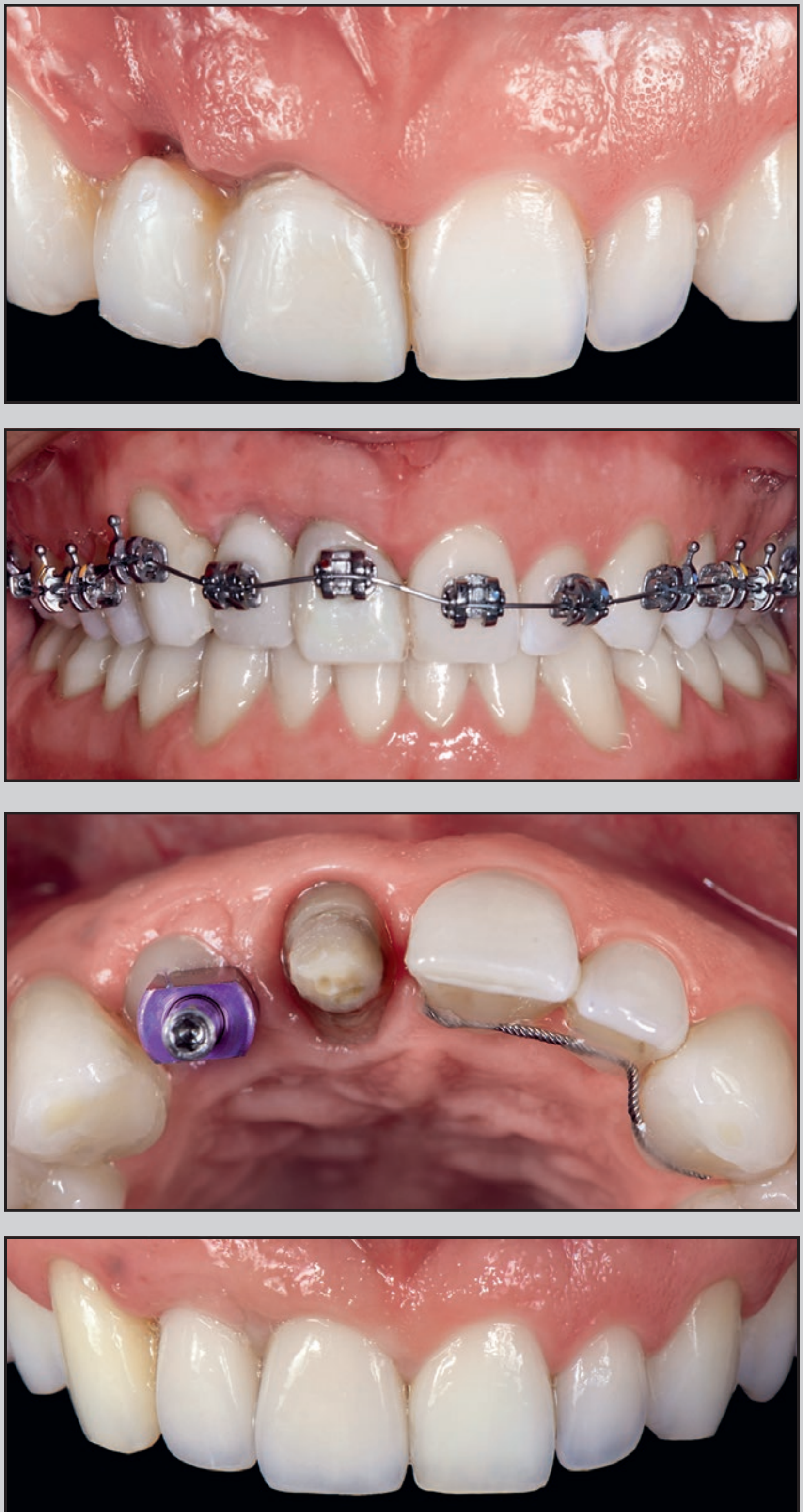

Orthodontic Extrusion: Guidelines for Contemporary Clinical Practice

Oscar González-Martín, DMD, PhD, MSc[1]
Belen Solano-Hernandez, DDS[2]
Ana Torres, DDS[2]
Saul González-Martín, DDS[2]
Gustavo Avila-Ortiz, DDS, MS, PhD[3]

Orthodontic extrusion (OE) is an orthodontic tooth movement in a coronal direction to modify the tooth position and/or induce changes on the surrounding bone and soft tissue with a therapeutic purpose. Evidence emanating from clinical reports and case series studies indicates that OE is a predictable treatment option to manage a variety of clinical situations. Common indications include traction of impacted teeth, exposure of teeth presenting structural damage to facilitate restorative therapy, treatment of periodontal bony and papillary defects, and implant site development. Unfortunately, there is a paucity of established protocols and guidelines for its application in clinical practice. Controversy exists in regard to the definition of rapid and slow OE, use of circumferential supracrestal fiberotomy, and tooth stabilization protocols during and upon completion of orthodontic movement. This article provides a concise perspective on the topic of OE by discussing key biologic principles and technical aspects that are translated into guidelines for the management of different clinical scenarios.
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[1]Department of Periodontology, Complutense University of Madrid, Madrid, Spain; Department of Periodontics, University of Iowa College of Dentistry, Iowa City, Iowa, USA; Private practice, Madrid, Spain.
[2]Private Practice, Madrid, Spain.
[3]Department of Periodontics, University of Iowa College of Dentistry, Iowa City, Iowa, USA.

Correspondence to: Dr Oscar González-Martín, Blanca de Navarra 10, Madrid (Spain) – 28010. Email: oscar@gonzalezsolano.com

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Orthodontic extrusion (OE), also known as orthodontic forced extrusion or orthodontic forced eruption, may be defined as an orthodontic tooth movement in a coronal direction to modify the tooth position and/or induce changes on the surrounding alveolar bone and soft tissue with a therapeutic purpose. OE is a versatile and minimally invasive treatment option that provides clinicians with a great deal of latitude and high predictability in the management of both routine and complex multidisciplinary cases.[1–3]

Multiple case reports and case series studies illustrating the therapeutic applications of OE have been published. However, there is a paucity of rigorous publications providing information to establish a clear differentiation between different OE modalities and their indication depending on the primary therapeutic goal and the characteristics of specific clinical scenarios. For example, the existing literature contains conflicting information regarding the use and timing of circumferential supracrestal fiberotomy (CSF) and tooth stabilization protocols. Another major point of controversy is the distinction between "rapid" and "slow" forced extrusion. While these terms are frequently used in the scientific literature and in daily clinical practice, the line separating the modalities is blurred.

Fig 1 *Extrusion of three maxillary incisors with a history of trauma through OE with CSF and no ITS.* (a) *Clinical and* (b) *radiographic situation prior to treatment, after removal of existing provisional crowns.* (c) *CSF and careful root planing were performed.* (d and e) *Frontal view at 30 and 45 days from baseline, respectively.* (f) *Tooth preparation. Note the increased ferrule and robustness of the stomps.* (g) *Provisional crowns prior to final prosthetic restoration.* (h) *Periapical radiograph upon completion of OE. This case was courtesy of Dr Yueh-Lung Wu, from a private practice in Taiwan.*

This article provides an updated and concise perspective on the indications and contraindications, biologic principles, and key technical aspects of OE, as well as guidelines for the management of different clinical scenarios leveraging on this treatment option.

Indications and Contraindications of OE

The main indications for OE in contemporary clinical practice can be classified into five categories:

1. Management of infraocclusal or impacted teeth.[4]
2. Exposing submarginal dental structure to facilitate the restoration of teeth presenting extensive damage, such as subgingival caries or transversal/oblique fractures and/or existing restorations impinging the supracrestal tissue attachment (Fig 1).[5]
3. Treatment of periodontal vertical/angular bone defects to reduce the infrabony component with the goal of improving tooth prognosis.[6,7]
4. Modification of the soft tissue envelope to correct inadequate gingival zenith position (Fig 2) and papillary deficiencies between two teeth (Fig 3) or between a tooth and an existing implant (Fig 4).[8]
5. Implant site development in preparation for prosthetic replacement of nonrestorable teeth (Fig 5).[9]

Fig 2 *Modification of the position of the gingival zenith and interproximal tissues using OE with no CSF or ITS to optimize the restorative outcome of a single-tooth–supported ceramic crown.* (a and b) *Initial clinical presentation of the maxillary right central incisor exhibiting midbuccal recession and deficient distal papillae.* (c) *Frontal view after 3 months of OE. Tooth stabilization lasted 4 months.* (d) *Final result. Note the stability of the soft tissue.*

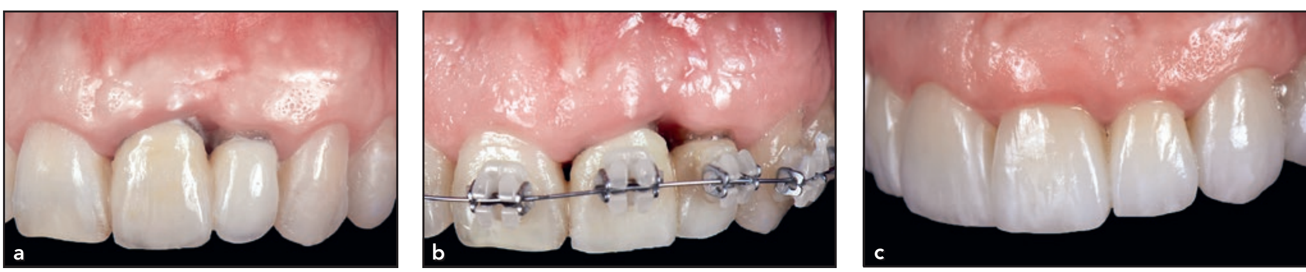

Fig 3 *Management of an interproximal papillary defect between two teeth using OE with no CSF and with ITS. These teeth had a history of trauma, endodontic therapy, subsequent apicoectomy, and bone grafting.* (a) *Lateral view upon initial clinical presentation.* (b) *Frontal view after 2 months of OE. OE continued for 3 to 4 weeks and alternated with 15-day intervals of ITS.* (c) *Final restorative outcome.*

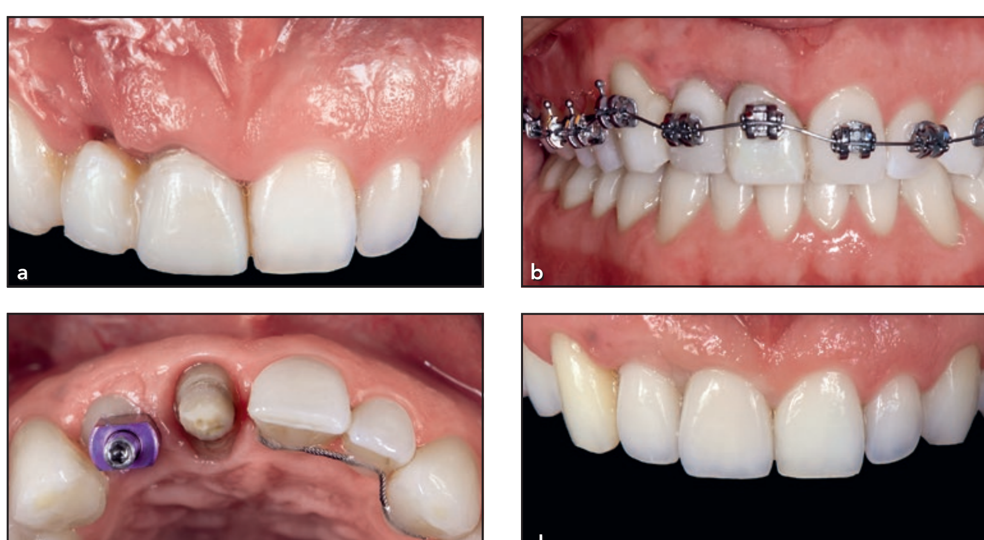

Fig 4 *Management of an interproximal defect between a tooth and an existing implant associated with a ridge defect using OE with no CSF and with ITS.* (a) *Initial clinical presentation. Note the significant buccal volume deficiency and lack of mesial papilla.* (b) *After localized soft tissue augmentation, a provisional implant restoration was delivered, and OE of the central incisor was initiated using the provisional implant-supported crown as anchorage. Tooth stabilization lasted 4 months after OE.* (c) *Soft tissue management using the concept of the critical and subcritical contours to optimize final appearance of the mucosa margin around the implant.* (d) *Final clinical result.*

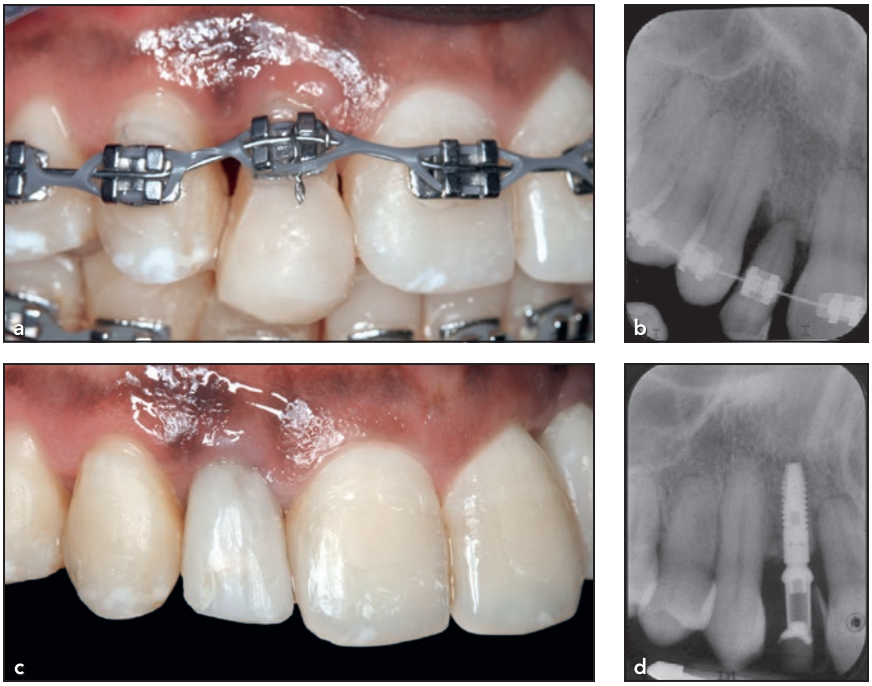

Fig 5 *Site development for implant-supported fixed dental prostheses using OE with no CSF and with ITS in the context of a complex case.* (a and b) *Forced eruption was done as part of comprehensive orthodontic treatment for a 20-year-old woman. Periodic occlusal adjustment is essential to avoid occlusal trauma during the tooth-movement phase to provide enough space for the eruptive movement. OE was done for 6 months and the tooth was stabilized for 4 months, as sufficient time for bone maturation is required in these cases.* (c and d) *Provisionalization after immediate implant placement. Note the coronal bone displacement accompanying forced tooth extrusion on the radiograph.*

Other indications for OE have been proposed in the literature. An example of that is slow, minimally traumatic tooth extraction when surgical extraction is contraindicated, such as in patients who are under treatment with intravenous bisphosphonates, to reduce the risk of osteonecrosis of the arches.[10] However, this specific application is supported by very limited evidence, and its practical application is questionable.

The main contraindications to OE are the following:

1. Vertical root fractures
2. Tooth ankylosis
3. Severe internal or external root resorption
4. Untreated periodontitis or periapical pathology
5. Severe medical conditions known to alter bone and/or collagen metabolism (eg, uncontrolled diabetes)

The Binomial Force-Time

The effect that orthodontic tooth movement exerts on the surrounding periodontal structures is primarily determined by the direction and magnitude of the force applied.

At the bone level, while pressure typically triggers a local physiologic response that results in the upregulation of osteoclastogenesis and, subsequently, bone resorption, tensile forces lead to bone apposition through increased osteoblastic activity.[11] At the soft tissue level, tooth extrusion causes supraphysiologic elongation of gingival collagen fiber bundles in a vertical direction, a response originally described by Oppenheim decades ago.[12] From a theoretical standpoint, pure orthodontic extrusive movements of single-rooted teeth with tapered roots do not exert compressive forces on the fibrous bundles of the periodontal ligament (PDL) and supracrestal soft tissue, only tension. As a consequence, extrusive tooth movements have the potential to induce the coronal displacement of the surrounding bone, which can contribute to correct severe anatomical deficiencies in specific situations. It has also been reported that the band of keratinized gingiva may increase in width after OE.[13] How can the desired therapeutic outcome be achieved in a predictable manner?

Preclinical histologic evidence and clinical data support the application of light, continuous forces to achieve orthodontic tooth movement.[14] However, the relationship between the direction and magnitude of the force, as well as the time required to obtain the desired tooth movement in the shortest period of time possible and in absence of adverse events, has been the subject of continuous debate in orthodontics. It must be acknowledged that a precise determination of the ideal correlation between orthodontic forces and tooth movement in a specific site is virtually unfeasible due to the large number of variables that may influence the extent of tooth displacement per unit of time in response to a given force. For example, key factors that may play a role in this equation in the context of OE are the amount of extrusion required, tooth type (single- vs multi-rooted), patient age (tooth movement is usually faster in younger patients), characteristics of the surrounding alveolar bone (tooth movement is usually faster through less mineralized bone), and viability of the PDL (eg, partial tooth ankylosis due to a history of trauma and/or endodontic therapy).[15]

A systematic review on the use of OE for implant site development found that both the total treatment time and orthodontic force applied were considerably variable across the selected literature.[16] Regarding time, it has been reported that tooth extrusion can be as slow as 1 mm per month[17] and as rapid as 1 mm per week,[18] with no clinically or radiographically apparent damage to the PDL. With respect to the force applied, Korayem et al concluded that, to allow for simultaneous bone and soft tissue displacement, light and constant extrusive forces should not exceed 15 g for anterior teeth and 50 g for posterior teeth.[16] However, depending on the therapeutic aim and local factors such as the root length and morphology and the density of the surrounding bone, the force required for effective extrusion may be as high as 50 to 75 g in certain cases.[19]

At any rate, it is evident that the binomial force-time is markedly site-specific. Hence, selection of the orthodontic force applied to obtain OE should be *(1)* based on a meticulous assessment of the characteristics of the site prior to the initiation of treatment, and *(2)* dynamically adjusted in periodic visits to obtain the desired outcome in absence of complications.

OE: Rapid or Slow?

In 1973, Heithersay proposed for the first time the use of OE with a therapeutic purpose other than orthodontic tooth alignment. The purpose of his landmark study was to investigate the possibility of managing endodontically treated teeth presenting subgingival and transversal root fractures by orthodontically moving the remaining root structure to a more coronal level that would allow for tooth restoration.[20] Two clinical protocols (neither involving CSF) were described in the article, but the effect that the speed of tooth movement had on the treatment outcomes was not addressed.

Pontoriero et al published in 1987 the first article introducing the term "rapid extrusion" to expose teeth presenting structural damage and facilitate their restoration.[21] According to the authors, the term "rapid extrusion with fiber resection" was chosen to describe their technique, based on the supposition that repeated sectioning of the supracrestal gingival fibers would lead to completion of the desired tooth movement in a shorter period of time. However, they also indicated that the original goal of performing fiberotomy was not to increase the speed of extrusion, but rather to eliminate excessive stress to the alveolar bone crest in order to minimize bone loss. Since the publication of this case series study, the term "rapid forced extrusion" has been historically linked to the resection of supracrestal fibers. However, CSF is not essential to obtain rapid extrusion.

In fact, Malmgren and collaborators described the use rapid OE without fiberotomy as an alternative procedure in 1991.[22] These authors indicated that, in spite of preserving the integrity of the supracrestal fibers, tooth inclination and bone remodeling should be minimal or nonexistent due to the rapid speed of movement, which was induced by the application of heavy forces and no intermediate tooth stabilization (ITS) periods. Interestingly, the authors recommended the performance of CSF after the necessary extrusion is achieved, immediately prior to the initiation of the stabilization period, in order to minimize relapse (ie, tooth intrusion).[22] Although it was pointed out that approximately 3 mm of extrusion was obtained in most patients after 3 to 6 weeks of active orthodontic force, the differences between rapid and slow OE protocols were not defined. Within the limits of the present authors' knowledge, only two articles to date (one case report[23] and one case series[24]) have utilized

Table 1 Details of Different OE Modalities

	Aim	Biologic rationale	Clinical protocol	Indications
OE 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 applying heavy forces with severance of supracrestal periodontal fibers and root planing, and without ITS.	• Expose submarginal tooth structure to facilitate restorative therapy
OE without CSF or ITS	Tooth extrusion with traction of gingival tissues and minimal or no alveolar bone changes.	Uninterrupted tooth extrusion with intentional elongation of periodontal fibers. Note: This approach may cause sulcular epithelium eversion and a subsequent recession defect.	Forced extrusion applying heavy forces with no CSF or ITS. 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
OE 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.	Forced extrusion applying light forces with no CSF and with periods of ITS.	• Management of impacted teeth • Treatment of periodontal infrabony defects • Modification of the soft tissue envelope • Implant site development

OE = orthodontic extrusion; CSF = circumferential supracrestal fiberotomy; ITS = intermediate tooth stabilization.

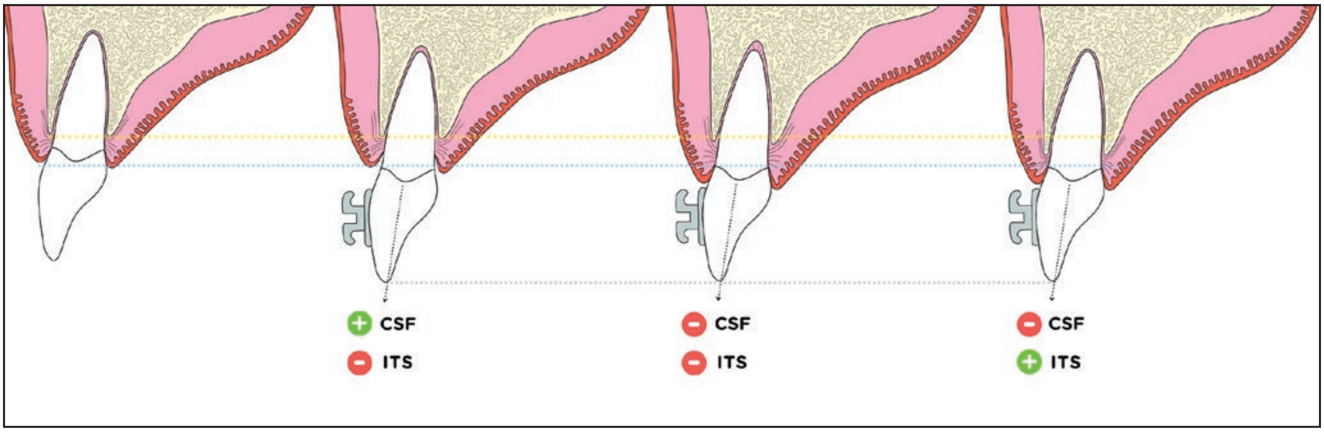

Fig 6 *Illustration demonstrating the effect of the gingival* (dotted blue line) *and crestal bone* (dotted yellow line) *level depending on the OE modality applied. CSF = circumferential supracrestal fiberotomy; ITS = intermediate tooth stabilization; + = present; – = absent.*

the term “slow OE.” However, other than indicating that the extrusion lasted 3 months, these articles did not provide any additional information on the clinical protocol.

It seems, therefore, that “rapid” and “slow” are largely unsubstantiated descriptors that have been used indiscriminately to characterize a variety of extrusive movements regardless of whether CSF and ITS periods are indicated.

OE Protocols in Contemporary Clinical Practice

Considering the limitations of the existing literature and on the basis of the present authors’ clinical experience, the following OE definitions and guidelines are proposed (Table 1 and Fig 6):

OE With CSF and Without ITS

This is a procedure aimed at inducing exposure of subgingival or subcrestal tooth structures for restorative purposes—through the application of heavy forces, no ITS periods, and severance of periodontal fibers and root planing (RP)—to prevent simultaneous displacement of the supporting bone and soft tissue (Fig 1). This approach is a tissue-preserving alternative to surgical crown lengthening (aka, resective tooth exposure), which may be particularly helpful in cases of high esthetic demand.

The combination of CSF and RP is recommended to sever the actual insertion of the gingival fibers and also prevent their reinsertion to the cementum and crestal bone during the healing period. CSF with RP may be performed once, before or after initiating the orthodontic movement, or repeated times in the course of therapy at intervals of approximately 15 days. The vector of movement in these cases usually follows the long axis of the tooth, unless correcting the position and/or angulation of the remaining tooth structure is required.

OE Without CSF or ITS

This approach involves the preservation and intentional stretching of supracrestal soft tissue fibers with the primary objective of vertically elongating the gingival tissue. OE without CSF or ITS may be indicated *(1)* to modify the soft tissue envelope and *(2)* for implant site development purposes, when modification of the bone level is not critical, as shown in some of the present cases (Fig 2).

In spite of not performing CSF, bone alterations would theoretically be minimal or nonexistent because of the absence of ITS and the nature of tooth movement, which is produced by heavy forces and frequent orthodontic activations.[22] However, bone changes with this approach are possible, though infrequent. Due to this inherent unpredictability, close monitoring is recommended during active orthodontic movement to implement protocol modifications, if necessary.

It is worth noting that rapid OE without CSF favors the occurrence of complete or partial sulcular epithelium eversion. When this phenomenon occurs, a red patch of varying intensity and extent is visible around the marginal mucosa, which may give the impression that an inflammatory process is ongoing. Probing depths (PDs) in this situation are usually minimal or even zero. A PD of zero is indicative of complete epithelial eversion and partial exposure of the most coronal aspect of the connective tissue insertion. In this situation, sustained local inflammation and/or trauma (eg, aggressive toothbrushing) may increase the risk of permanent gingival recession. With proper care and adequate tooth stabilization after the desired amount of tooth movement has been reached, the sulcus is spontaneously reestablished and superficial keratinization occurs following a variable period of time.[25,26]

It is also important to note that OE without CSF or ITS does not allow for the reorganization of the supracrestal fibers during the period of active tooth movement. Therefore, the stabilization period after tooth movement is typically the longest of the three OE alternatives hereby described.

OE Without CSF and With ITS

This procedure aims to induce tooth movement in a coronal direction by applying continuous and light forces, compatible with conventional orthodontic protocols, over a variable time period with no CSF and with ITS periods. This approach usually requires less frequent orthodontic activations compared to the other two modalities, but it requires ITS periods. ITS has important practical implications, since it allows for the reorganization of the supracrestal fibers and new bone apposition as the tooth movement progresses. In this modality, the vertical movement intended may not necessarily follow the long axis of the tooth, depending on the desired therapeutic effect, such as in cases of tooth impaction and implant site development.[27,28]

This approach may be indicated to manage impacted teeth,[4] to improve the periodontal status of teeth presenting localized vertical defects,[7] to correct interproximal papilla defects, or as an implant site development approach, when modification of the bone level is critical.[9] When feasible, slow OE represents a minimally invasive and predictable treatment to avoid or reduce the need for implant site development surgery, such as horizontal and vertical bone augmentation via guided bone regeneration and/or soft tissue augmentation using autogenous soft tissue grafts.

It is generally acknowledged that this clinical protocol allows for tooth movement and simultaneous displacement of the surrounding bone and soft tissue at an approximate rate of 0.5 to 1 mm per month.[16] However, as previously mentioned, the total duration of treatment is primarily influenced by local anatomical factors (eg, root length and morphology, bone density) and, of course, the ultimate therapeutic goal.

Clinical Considerations During and After Active OE

Independent of the clinical protocol applied, patients undergoing OE should be evaluated in short, regular intervals of 1 to 2 weeks in order to monitor their oral hygiene, modify the orthodontic appliance, assess and adjust occlusion if necessary, and determine whether the desired amount of extrusion has been attained.

When performing OE procedures, it is also important to consider how much the PDL and supracrestal connective tissue fibers, if no CSF is done, can be stretched without causing irreversible damage. It is generally acknowledged that the chances of severe root resorption are increased if a rapid (ie, application of heavy forces) orthodontic translation or intrusion is performed,[29] but this does not seem to be the case in regards to extrusive movements. Even though a case report suggested that OE was associated with root resorption of a traumatized maxillary central incisor,[30] in light of the body of evidence regarding this topic, it can be considered a rare adverse event.

Once the required amount of extrusion has been achieved or if new bone apposition is intended, final or intermediate tooth stabilization is necessary to allow for complete maturation of bone, PDL, and gingival tissue and to minimize the chances of a relapse.[19] This is particularly crucial in sites planned for implant placement in order to minimize the risk of unfavorable tissue remodeling before or after implant insertion. However, there is no consensus regarding the stabilization time needed in function of the modality applied and the ultimate therapeutic goal. Korayem et al indicated that the range of ITS periods reported in the articles included in their systematic review[16] varied widely, from 0 days (in a case report of extraction and immediate implant placement[31]) to 6 months, with an average stabilization time of 9.3 weeks. This is within the general range of 6 to 12 weeks proposed by other prominent authors.[19] It is also worth reiterating that, due to the nature of OE without CSF or ITS, the final stabilization time required to avoid a relapse and obtain tissue maturation should be longer than the other treatment modalities.

Originating in the clinical recommendations by Malmgren et al,[22] the general consensus seems to be that CSF, regardless of whether it is done before or after active orthodontic movement, contributes to minimizing intrusive relapse. This has been validated by the findings reported in a clinical trial conducted by Carvalho et al[32] and is compatible with the observations from clinical studies involving rotational and translational tooth movement.[33,34] However, even if CSF is performed, clinicians must be aware that a variable degree of relapse can occur and additional orthodontic therapy or surgical correction may be necessary.

A periapical radiograph may be obtained to verify that bone formation in the apical space created as a consequence of tooth extrusion has occurred in order to determine whether the tooth has been stabilized for sufficient time. After this is verified, the orthodontic appliances may be replaced with other retention devices, such as conventional fixed wire splinting or a provisional fixed dental prosthesis, depending on the restorative treatment plan.

Conclusions

OE is a predictable therapeutic option for the effective management of a variety of clinical scenarios. There are no universal parameters that define rapid or slow OE, as there are multiple variables that may play a role in the selection of a specific protocol for tooth movement. The total time of active OE is primarily influenced by the clinical protocol applied (the magnitude of the orthodontic force and whether CSF or ITS are performed), amount of tooth extrusion desired, and root morphology.

To the present authors' knowledge, there are no published articles regarding complications or failure of this technique. However, the scientific evidence supporting OE primarily derives from case reports and case series studies. Further clinical and translational research is warranted to test the efficacy of OE compared to other modalities of treatment in order to develop evidence-based clinical protocols for the application of OE in specific clinical scenarios.

Acknowledgments

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Erratum

In the article by Bhatavadekar et al (Long-Term Outcomes of Coronally Advanced Tunnel Flap [CATF] and the Envelope Flap [mCAF] Plus Subepithelial Connective Tissue Graft [SCTG] in the Treatment of Multiple Recession-Type Defects: A 6-Year Retrospective Analysis) in Volume 39, Number 5 (September/October), 2019, the number of incisors and canines that were included in the study and the baseline and 6-year probing depths were incorrectly reported in the Results text. The correct number of incisors and premolars are 34 and 22, respectively, and the correct baseline and 6-year probing depths are 1.67 ± 0.76 mm and 1.63 ± 0.68 mm, respectively, as reported in Tables 1 and 2. This has been corrected in the online version of the article.
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