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Review

Staging of Orthodontic Tooth Movement in Clear Aligner Treatment: Macro-Staging and Micro-Staging—A Narrative Review

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Abstract: Aims: This review aims to analyze the multiple factors affecting the staging of the orthodontic tooth movement during clear aligner treatment and to provide an efficient work methodology in this regard during digital treatment planning. Materials and Methods: A literature search was conducted on electronic databases (Pubmed, Scopus, Google Scholar and CNKI). The results of the present study have been divided into several sections: (1) definition and concept of staging, (2) basic principles of clear aligners, (3) macro-staging, (4) micro-staging, and (5) limitations. Results: The terminology of macro-staging and micro-staging proposed in this paper aims to be a first step towards a more detailed analysis of staging. The macro-staging constitutes the general biomechanics of movements that need to be prioritized to meet the objectives of the treatment plan. It provides a comprehensive view of the movements occurring in each dental arch. The micro-staging constitutes the biomechanics of movements for each individual tooth. This involves studying the movements in the different planes of space in which each tooth is programmed, deciding if they are compatible, and having strategies to create space to avoid lack of expression. Conclusions: Further studies should focus on exploring different staging approaches to address similar malocclusions to determine which are the most effective and applicable to clinical practice.

Keywords: clear aligners; staging; orthodontics tooth movement; macro-staging; micro-staging

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1. Introduction

Orthodontics with clear aligners is part of the daily routine for orthodontists due to patients' esthetic demands and comfort [1–3]. Some of the advantages offered by clear aligners are esthetics, comfort, improved oral hygiene and periodontal health, minimal emergencies, decreased dental office visits, no food restrictions, and digital planning preview [3]. The development of invisible orthodontic technology has allowed clinicians to surpass the original indications of clear aligners like mild crowding (1–5 mm), spacing (1–5 mm), or narrow arches that can be expanded by buccal crown tipping [4]. However, systematic reviews [5–7] or predictability studies [8–10] report discouraging success rates that raise questions among orthodontists about the effectiveness of treatment with clear aligners. According to the latest reports, vertical movements without changes in inclination (particularly the intrusion of incisors) and the rotation of teeth with rounded shapes (such as lower canines and premolars) are difficult to correct with clear aligners [11]. Limitations have also been found in treatments that require considerable root movement, characteristic of cases involving premolar extractions with space closure [12] or palatal torque changes of the incisors [13]. One problem contributing to this lack of efficacy is the influence of multiple factors surrounding treatment with clear aligners [14], highlighting the dependency on patient compliance. While attachments [15,16], the frequency of aligner changes [17,18], and overcorrection [19] have garnered attention from researchers, staging of orthodontic tooth movement has been the focus of only a limited amount of specific literature [20]. Increasing scientific interest in the staging can be beneficial for developing precise work protocols and identifying potential errors, thus justifying the differing results among studies evaluating the same mechanics [21–23]. An evaluation of the current information available in the scientific literature on staging orthodontic tooth movement is necessary to guide future specific research on the topic. A narrative review allows for an initial pedagogical approach due to the absence of specific studies on the selected topic.

2. Aim and Objectives

The objective of this narrative review is to define and structure the staging of orthodontic tooth movement, introducing new terminology associated with more efficient virtual planning that relies on the intrinsic characteristics of clear aligners to optimize outcomes and to help orthodontists become more efficient with their virtual planning in invisible orthodontics.

3. Methods

A literature search of relevant articles that directly or indirectly analyzed the influence of staging in orthodontic treatment with clear aligners was conducted on electronic databases (Pubmed, Scopus, Google Scholar and CNKI) from January 2000 up to January 2024. Additionally, information obtained from chapters of major books published on invisible orthodontics that discussed staging was included. The authors also included articles from their personal library that were not found via the previously mentioned search platforms using keywords like "staging", "stadification", "orthodontic sequence", "orthodontics tooth movement", and "clear aligner treatment".

When the literature was reviewed, the narrative review was structured into several sections to make its organization more precise: (1) definition and concept, (2) basic principles of clear aligners, (3) macro-staging (subdivided into three sections), (4) micro-staging (subdivided in four sections), and (5) limitations.

4. Results and Discussion

4.1. Definition and Concept

The concept of sequence or "*staging*" was first described in the literature by Sterental [24] as the "*collection of stages and procedures used to achieve the position of the teeth using the Treat software*". Technicians would establish the final target position of the treatment and divide the required dental movement into different stages corresponding to each aligner. The concept of staging evolved into a more "*biological*" ideal deeply connected to anchorage, adding the suffix "*of orthodontic tooth movement*". Thus, Metha et al. [20] define "*Staging of orthodontic tooth movement*" as the "*breakdown of the predicted movement of the teeth sequentially with aligners*". The importance of this concept lies in understanding the principles of orthodontic tooth movement and its application with aligners [25].

Staging should not be confused with "*stadification*", which refers to the amount of movement (linear and/or angular) programmed for each tooth in each aligner. "*Staging*" is related to the number of teeth in movement and the immobile teeth used as anchorage during the progress of treatment with aligners.

An approach to this staging–anchorage relationship was described by Sterental [24] in 2006, dividing the staging into two categories: (1) a low anchorage pattern or "*X*" pattern, where all the teeth in the arch move simultaneously, and (2) a high anchorage pattern or "*V*" pattern, where some teeth in the arch remain immobile at different stages of treatment to maximize anchorage. The choice between these patterns depended on the case's complexity and anchorage demands, influencing the programmed stadification. In a low anchorage pattern, Invisalign (Align Technology, San Jose, CA, USA) software allowed a maximum linear speed of 0.25 mm and a rotation of 3° per aligner stage.

In the high anchorage pattern, however, posterior teeth could move a maximum of 0.33 mm per aligner (since this pattern was used in cases involving distalization) [24]. Currently, the maximum values per stage in the Invisalign system are independent of the proposed staging (0.25 mm for linear movements, 1° for angular movements, and 2° for rotations) [26].

4.2. Basic Principles of Clear Aligners

In order to understand the complexity and importance of the staging in treatment with clear aligners, it is advisable to emphasize the fundamental principles that characterize these systems and differentiate them from conventional multibracket fixed orthodontic systems [3].

From the authors' perspective, there are three fundamental principles:

1. A closed system.
2. Push surfaces.
3. Differential anchorage.

A closed system is one that does not allow a release of forces at its ends. Multibracket fixed orthodontic systems are often considered open systems as they manifest excess energy in the most distal elements of the system. An example of this occurs during the alignment and leveling phase with nickel–titanium round archwires in cases with significant dental crowding. As the archwire regains its original shape and "*pulls*" the teeth toward the new arch form, it generates a set of forces (or energy) whose remnant is expressed in the distal part of the last bonded molar tube as excess arch.

In contrast, clear aligner orthodontics is organized through a system in which the aligner completely covers the dental crowns. Since it lacks an open or free area in the scheme, the forces introduced into it will persist and can cause undesired movements if there is insufficient space in the arch (resulting in dental intrusion or the "*watermelon seed effect*", as described in the literature [27,28]).

The practical implication of working in a closed system is that the clinician must focus on continuously creating space in their planning [3], whether through planned expansion, buccal inclination of the crowns, interproximal enamel reduction, tooth extractions, or distalizations. The visual creation of space forms an essential part of the sequencing of movements, as we will explore further.

In fixed multibracket orthodontic systems, we have two elements: the archwires, which constitute the active component as they are responsible for exerting forces on the teeth, and the brackets, which form the passive component by acting as a connection between the archwire and the teeth (although they also provide information about tip and torque through their prescription). In clear aligner orthodontic systems, the aligners constitute the active element as they apply pressure to the teeth through push surfaces [4]. Each aligner slightly modifies the position of each tooth by exerting forces on millions of points on the dental crowns, creating an appliance with a shape slightly different from the teeth it encompasses. The flexibility of the plastic allows for a controlled adjustment period called the "*interphase*" [29,30], which is crucial for the efficient functioning of invisible orthodontics. If there is space between the teeth, dental movement occurs after a few days, aligning the shape of the aligner with the shape of the teeth. However, precise mechanisms detailing when an aligner has fully expressed its information over time have not yet been developed, causing the pattern of changing aligners to be based on the professional's decision. Because the aligner has the same shape and size as the teeth it encloses, dental anatomy significantly influences the effectiveness of tooth movement [31]. The design of wide push surfaces forms a relevant part of the staging of movements, as will be explained later.

Differential anchorage [32,33] is a highly valuable feature of clear aligner orthodontics that involves establishing a staging of movements where there is always a greater anchorage value (represented by unmoving teeth) than teeth in displacement [34,35]. This concept minimizes the movements of teeth used as anchorage [36] and maximizes the movements of target teeth. Moreover, differential anchorage provides the flexibility to modify anchorage segments throughout the treatment according to the clinician's needs [37]. Differential anchorage is the core of the staging of orthodontic tooth movement.

4.3. Macro-Staging and Micro-Staging

The introduction and popularization of the "*new aesthetic paradigm*" in orthodontics in the 1990s, as introduced and popularized by Dr. Sarver [38], brought about the need for structuring and classifying the new concepts to facilitate their practical application among orthodontists. Sarver and Ackerman proposed dividing esthetic analysis into three sections: macroesthetic (related to the face, its harmony, and proportions), miniesthetic (focused on the relationship of the lips and soft tissues with the teeth), and microesthetic (centered on the arrangement of teeth in the arch, shape, size, proportion, etc.) [39].

We believe that to encompass the possibilities offered by the staging with aligners, it is also necessary to create a division between two fundamental sections: macro-staging and micro-staging. Separating both analyses allows for the detection of potential issues in the follow-up of virtual planning.

4.3.1. Macro-Staging

Macro-staging constitutes the general biomechanics of movements that need to be prioritized to meet the objectives of the treatment plan. It provides a comprehensive view of the movements occurring in each dental arch. This generalized sectional study of the sequence analyzes the overall anchorage pattern, helping us determine if there are solid support points throughout the staging to ensure dental movement. Additionally, it must be determined whether the overall dental movement is synergistic or antagonistic, as it influences the predictability of results.

To review whether a plan has appropriate macro-staging, the clinician must complete the following steps:

1. Define the general biomechanics of malocclusion correction.
2. Create the necessary conditions to make these biomechanics as predictable as possible.
3. Establish the distribution and sources of anchorage.

Define the General Biomechanics of Malocclusion Correction

The first decision the orthodontist must make is to opt for a *simultaneous pattern* of movements (where all or practically all teeth in the arch move at once) or a *structured pattern* (where there are always immobile teeth acting as anchorage while others move). This decision depends on many factors, with the most relevant being the complexity of the malocclusion. Severe malocclusions requiring complex dynamics (such as distalization or closing extraction spaces) benefit from a structured pattern. Simple malocclusions that can be resolved with highly predictable movements that also create space (such as posterior expansion or proclination of anterior teeth) may benefit from a simultaneous pattern, as it reduces the number of active aligners and increases efficiency [40]. Other factors influencing decision-making include the selected sources of anchorage, the individual situation of each tooth, the bone and periodontal support, and the pattern of appliance changes.

The types of movements required also impact the predictability of the macro-staging. The ability to combine synergistic movements enhances the force systems generated by the plastics and is desirable when planning.

Some synergistic mechanics include posterior expansion + anterior retrusion, proclination or expansion + hinge rotation, posterior compression + anterior protrusion, posterior distalization + anterior proclination, posterior extrusion + anterior intrusion, or posterior intrusion + anterior extrusion (Figure 1A).

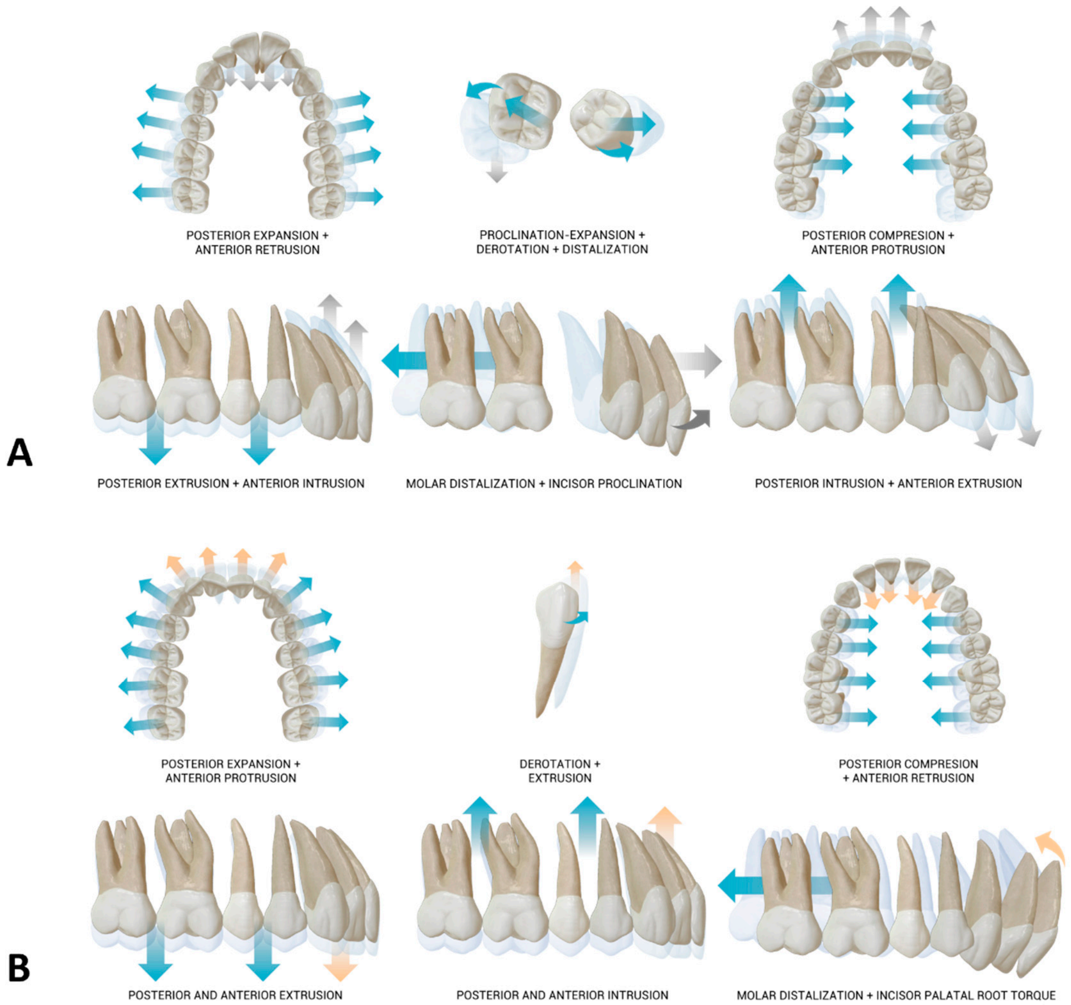

Figure 1. (**A**) Synergistic movements. (**B**) Antagonistic movements.

On the other hand, antagonistic movements are not desirable, as they diminish their expression and can lead to arch collapse, causing a "*loss of tracking*". The orthodontist should avoid, in the analysis of the macro-staging, the simultaneous occurrence of these dynamics. Some antagonistic mechanics include posterior expansion + anterior protrusion, rotation + extrusion, posterior compression + anterior retrusion, simultaneous posterior and anterior extrusion, simultaneous posterior and anterior intrusion, or posterior distalization + palatal root torque (Figure 1B).

Create the Necessary Conditions to Make These Biomechanics as Predictable as Possible

This aspect is highly individualized to each patient, but in general, all macro-stagings benefit from establishing the timing of each movement (for example, "*first alignment by expansion and proclination, then extrusion*"), aiming to combine synergistic movements simultaneously and selecting the best auxiliary resources for each phase of the sequence. This implies, for example, that during the derotation of a tooth, it may have an attachment to assist with rotation, but when the planned extrusion arrives, this attachment should be replaced with one designed to assist with extrusion. Using an intermediate attachment design that can help both with rotation and extrusion will be less effective than a specific design for each phase (Figure 2).

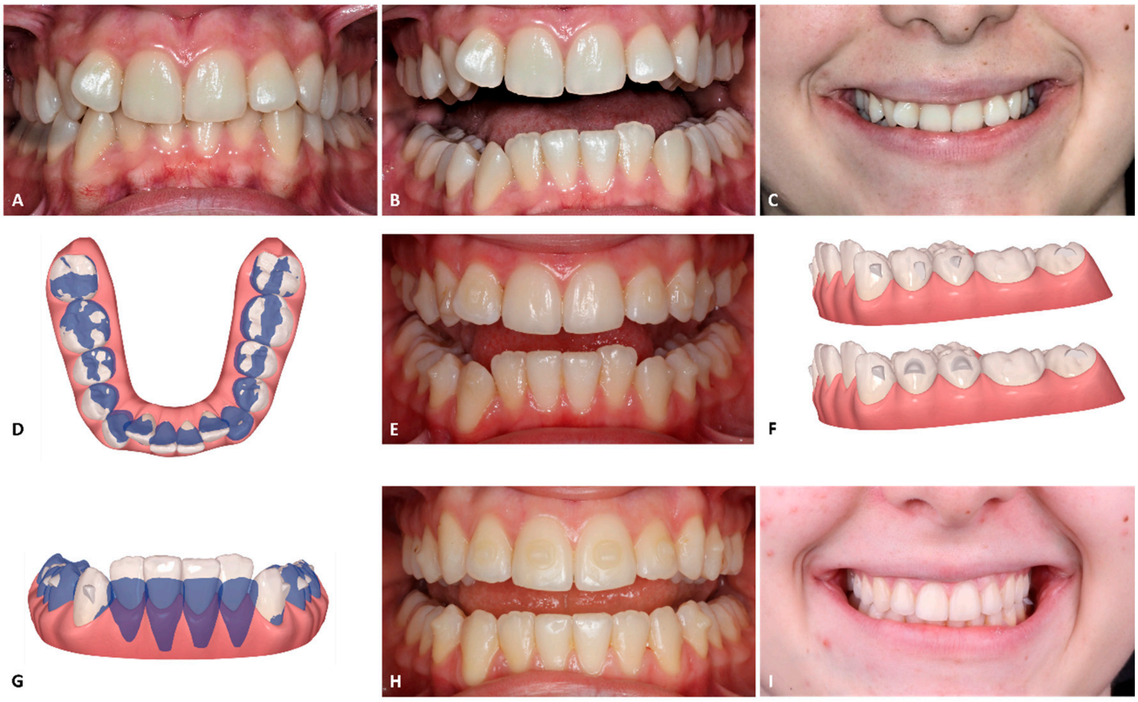

Figure 2. Creating the necessary conditions to maximize predictability. Teen patient with crowding, increased overbite, and pronounced lower Spee curve (**A**,**B**). During the macro-staging, it was established to reduce the overbite through relative and absolute intrusion of the lower anterior teeth due to their mid-line smile (**C**). From aligner #1 to #27, the alignment and leveling of premolars and molars were programmed to reinforce the posterior anchorage segments, simultaneously derotating the canines and aligning the incisors by tipping the crowns labially (**D**). Intraoral situation at aligner #28 (**E**). Optimized rotation and optimized root control attachments for the lower premolars were replaced with optimized deep bite attachments to increase posterior retention (**F**). From aligner #28 to the end, absolute intrusion of lower incisors was performed (**G**). Intraoral situation at the end of the first set of aligners, with a flat lower Spee curve (**H**). Patient's smile at the end of treatment (**I**).

Establish the Distribution and Sources of Anchorage

Clear aligner orthodontics has three possible sources of anchorage that can be combined or used individually: (1) differential intra-arch anchorage, (2) inter-arch anchorage with elastics, and (3) skeletal anchorage. The selection of anchorage at this point defines the strategy. The same staging of movements is not programmed for a patient planning upper arch distalization using only intra-arch anchorage compared to combining it with the use of skeletal anchorage. In the first situation, the orthodontist should be more careful with the anchorage balance, moving at most two teeth at a time per hemiarch [22,41], whereas if skeletal anchorage is strategically employed, more teeth can be moved simultaneously, compensating for the lack of intra-arch anchorage [42,43].

Among the possibilities that can be planned during the macro-staging, there are three mechanics that are especially dependent on a structured staging: (1) distalizations or mesializations, (2) absolute vertical movements of anterior teeth, and (3) closing extraction spaces [21].

The standard staging for the distalization of upper molars was described by Daher [44] as follows: "*The distalization starts with the upper second molars, and once the second molars are* $^2/_3$ *of the way, then the upper first molars move back, then premolars, and so on. For the anterior teeth, distalize the canines, and then distalize/retrocline the upper incisors*". With slight modifications, this proposal evolved into the sequential distalization $^1/_2$ pattern, where at most two teeth are moved per hemiarch, except for the incisors, which are treated as a single block. This staging has been used by several authors, achieving bodily movement of upper molars of up to 3 mm without appreciable vertical changes [22,40].

It is crucial to note that no more than two teeth per quadrant are moved simultaneously, as sometimes simultaneous displacement of the first premolars, canines, and incisors can occur because the algorithm tries to avoid opening spaces between the upper lateral incisors and canines when a standard sequential distalization pattern is requested with Invisalign [45]. The difference between a real $^1/_2$ pattern and a false $^1/_2$ pattern can be observed in Figure 3. There is a variation of the $^1/_2$ staging that includes buccal crown inclination movements of incisors during molar distalization [45]. This modification does not significantly impact performance, as it benefits from the synergistic mechanics of both movements and allows for the accelerated anterior esthetic improvement of the patient. Despite this, to date, we have not found publications that compare different distalization staging and their efficacy in the clinical setting.

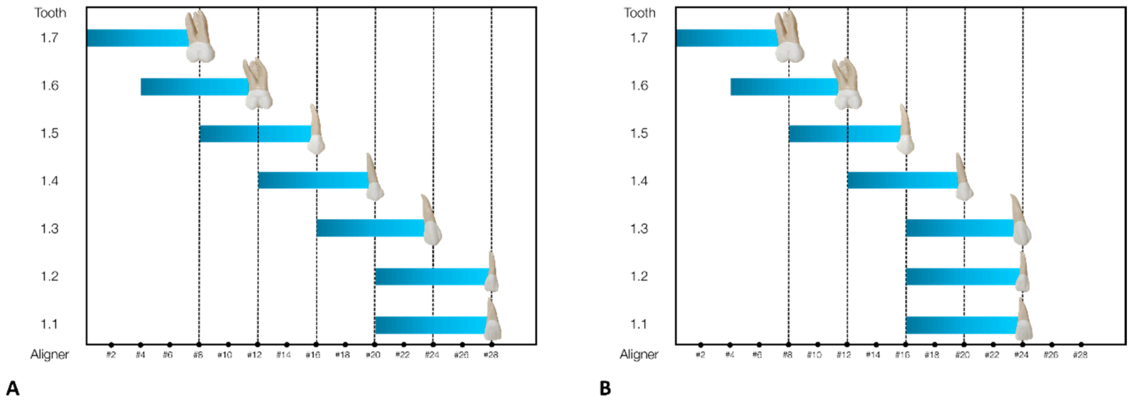

Figure 3. The pattern of sequential $^1/_2$ staging is the most popular among orthodontists [22,40]. (**A**) Real sequential $^1/_2$ staging, in which the movement begins with the second molar, and when it reaches halfway, the first molar begins to move. When the second molar finishes its movement, the second premolar starts to move. The staging continues, moving at most two teeth per hemiarch until the distalization of the first premolar is completed, at which point the incisors move along with the canine (three teeth in simultaneous movement). (**B**) False sequential $^1/_2$ staging, which begins by following the previously described sequence until the distalization of the second premolar is completed, at which point the first premolar, canine, and incisors are in motion (four teeth in simultaneous movement), with the potential risk of anchorage loss.

Absolute vertical movements are complex and are associated with low predictability [46,47] or frequent loss of tracking. Flattening the Spee curve deserves special attention during the staging due to negative reports regarding its management with clear aligners [48,49]. To achieve a more effective anterior intrusion, we suggest organizing the Spee curve flattening staging into three phases: (1) alignment of anterior teeth (by buccal crown inclination and derotation) along with the preparation of anchorage in the posterior sectors (derotation and leveling of premolars), (2) intrusion of canines with or without simultaneous premolar extrusion, and (3) intrusion of incisors [50] (Figure 4).

This strategy, in our opinion, presents several advantages:

1. The first phase of alignment and anchorage preparation creates space in the anterior segment, alleviates crowding, and isolates absolute vertical movement for the final stage. It also allows the apex of the incisors to be relocated away from the cortical bone to avoid possible dehiscence or blockages during intrusion [51,52]. Additionally, the anchorage provided by rotated or compressed posterior segments is less than that provided if they are correctly aligned and leveled.
2. Separating the intrusion movement of canines and incisors enhances the intrusive force on the target teeth and reduces the extrusive counterforce on anchor teeth. This is reflected in the study by Liu and Hu [53], which demonstrated greater intrusive efficacy in models where only lower canines were intruded or only lower incisors were intruded.

3. Simultaneously requesting premolar extrusion with canine intrusion enhances both movements.
4. This scheme allows the use of rotation attachments, expansion control, or root control attachments on canines and/or premolars for the first phase of movement, to be replaced by retentive attachments when vertical movements begin.

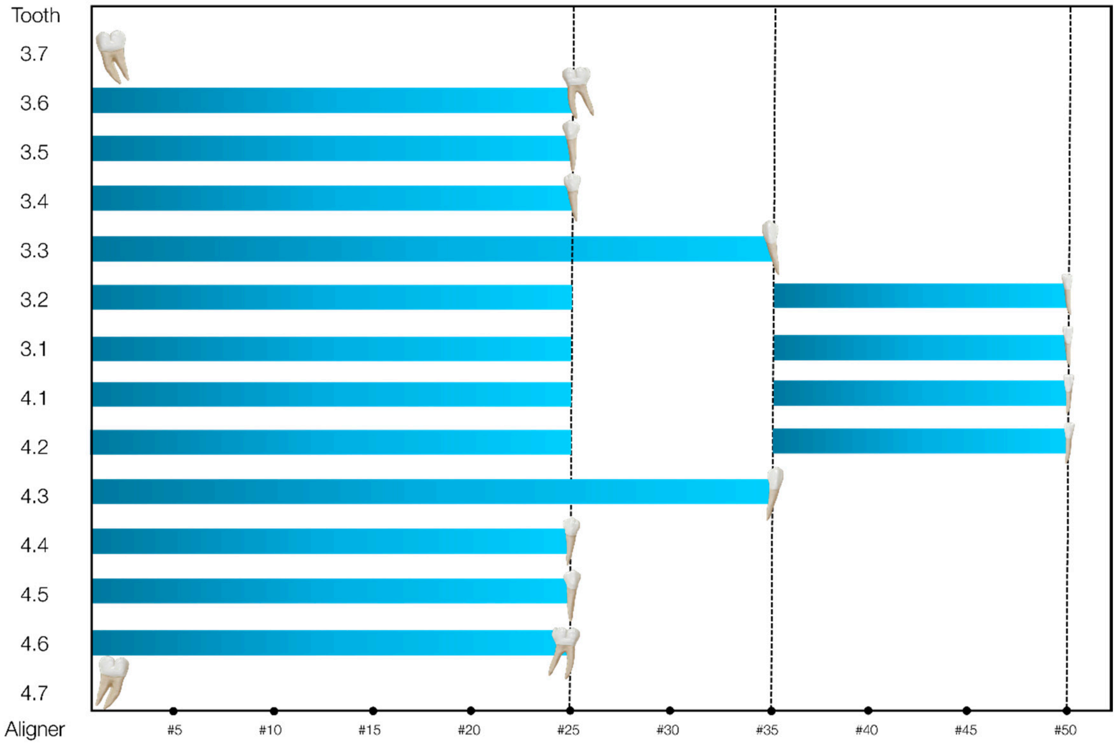

Figure 4. Configuration of the lower staging to flatten a pronounced Spee curve emphasizing anterior intrusion. In the first phase (aligners #1 to #25), dental alignment, derotation, and leveling of both anterior and posterior teeth are performed. In the second phase (aligners #26 to #35), isolated intrusion of lower canines is carried out (absolute premolar extrusion could also be programmed if posterior extrusion is desired). In the third phase (aligners #36 to #50), absolute intrusion of incisors is performed.

Figure 2 is an example of the results obtained using this staging of movements.

This same approach of macro-staging that starts by aligning the anterior segments to then perform isolated pure vertical movement can also be used for anterior extrusion.

The staging in cases of extractions and large space closures is complex, as it must reduce the risk of a bowing effect by trying to control the retraction of anterior teeth with torque control while also attempting to shift the root apices in mesiodistal movements [54,55]. An interesting proposal was detailed by Samoto and Vlaskalic [56], and it is now referred to as segmental tooth movements or "*caterpillar motion*" [57]. Extraction spaces would be closed in several stages of posterior alignment and canine retraction followed by incisor retraction (Figure 5). The proposal of segmented movements maximizes intra-arch anchorage and promotes root movement by allowing "*pause*" stages while other teeth are in motion [58]. To organize segmental tooth movements, it is important not to simultaneously shorten both ends of the arch to avoid bending the plastic and favor a bowing effect. Additionally, having immobile teeth throughout the treatment in intermediate segments of the arch seems to favor the correct movement of adjacent teeth and increase anchorage [59].

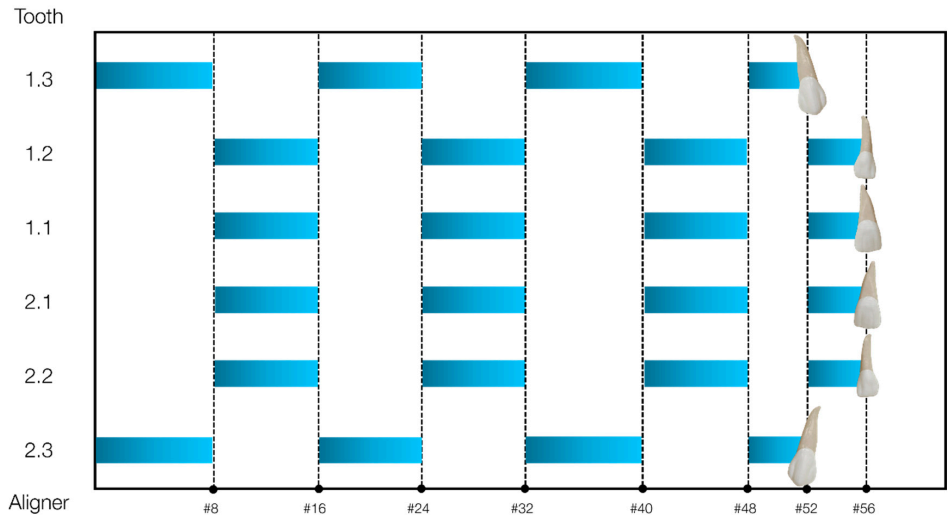

Figure 5. Configuration of segmental movements for a 7 mm extraction space closure. Stages of movement are alternated over 8 aligners (0.25 mm per aligner, 2 mm encompassing 8 aligners) between canines and incisors.

4.3.2. Micro-Staging

Micro-staging constitutes the biomechanics of movements for each individual tooth. This involves studying the movements in different planes of space that each tooth is programmed for independently, deciding if they are compatible, and having strategies to create space to avoid lack of expression and, consequently, unwanted intrusion.

To review whether a plan has an effective micro-staging, the clinician must complete the following steps:

1. Define the individual biomechanics of each tooth.
2. Determine the need for spacing movements (priority of movements).
3. Identify interproximal friction points and facilitate plastic push.
4. Observe precontact or overlaps during movement.

Define the Individual Biomechanics of Each Tooth

The first exercise involves defining the positional defect of each tooth to establish what movements are necessary to correct its placement. The available movements are grouped into the following categories: (1) bucco-lingual crown inclination change, (2) bucco-lingual root inclination change, (3) rotation, (4) mesio-distal inclination change, (5) bucco-lingual position change, (6) mesio-distal position change, and (7) vertical position change.

The dental movement table incorporated in most aligner planning software can assist the orthodontist in understanding the amount of correction for each movement.

Determine the Need for Spacing Movements

Like with macro-staging, it is necessary to know whether the movements required for dental correction can be performed simultaneously or if it is advisable to separate them into different phases. There is no absolute criterion that can be applied to all situations, but generally, it is favorable to start with movements that create space in the arch, such as expansion or proclination, as any movement that consumes space (such as compression or extrusion) can block the rest of the movements. Prioritizing movements of crown inclination before movements requiring displacements of the root apex is interesting, as they have a high predictability of success [4]. Lastly, more complex movements, especially absolute vertical movements, should be postponed, as they often require overcorrection or auxiliary elements.

An example is shown in Figure 6, where the lower right canine requires several movements for correction. First, a buccal crown inclination (space creation) was performed and combined with slight intrusion (favorable due to the relative intrusion component of the proclination of the tooth) and a distal-out hinge rotation (in favor of expansion). These combined movements created space on the distal face of the canine, allowing time for the rearrangement of the lower incisors to obtain space mesial to the canine. In a second set of movements, lingual root inclination with mesial root tipping was performed (so that the aligner would push near the mesial gingival margin of the canine).

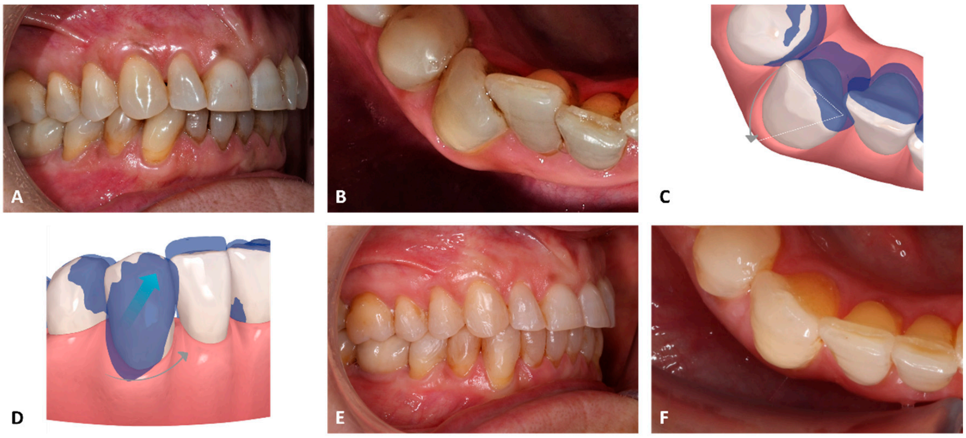

Figure 6. The lower right canine of the patient was crowded, with a crown inclination towards mesial, the root apex distally positioned, and the distal face compressed (**A**,**B**). The micro-staging was divided into two phases; first, distal-out hinge rotation was programmed along with buccal crown inclination to create space (**C**), then radicular straightening towards mesial along with lingual root torque (**D**). Canine position at the end of the first set of aligners (**E**,**F**).

In the case shown in Figure 7, the expansion and alignment of the second quadrant molars were prioritized first (good predictability and space creation), and absolute intrusion was postponed to the end (in case the placement of miniscrews became necessary).

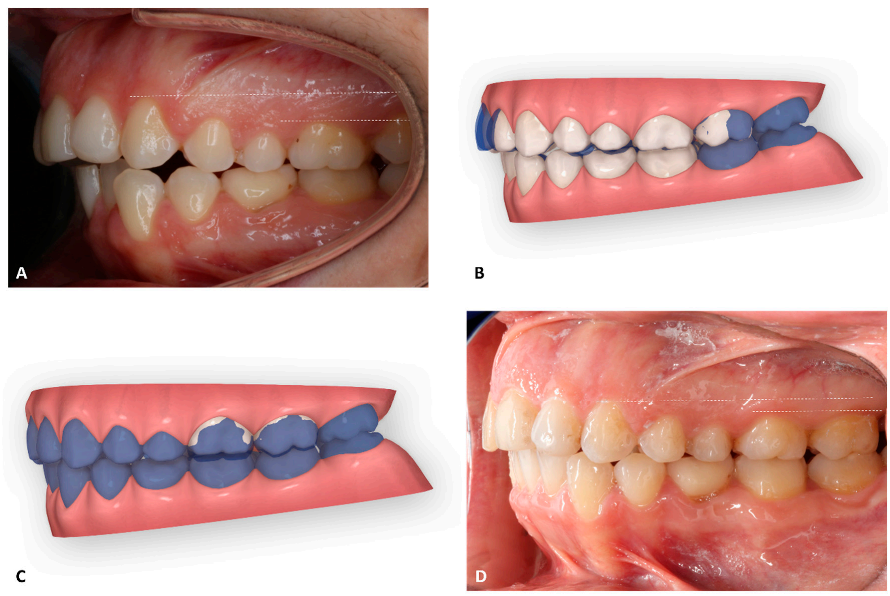

Figure 7. Patient with left Class II, increased overjet, and gingival unevenness between the anterior and posterior segments (**A**). The micro-staging was divided into a first phase of posterior expansion and anterior retraction to produce relative intrusion and molar derotation (**B**) and a second phase in which the isolated intrusion of first and second molars was planned (**C**). At the end of the first set of aligners, a reduction in gingival unevenness between the gingival margins of the molars and the anterior teeth was observed (**D**).

Identify Interproximal Friction Points and Facilitate Plastic Push

The second principle of orthodontics with clear aligners emphasized the importance of having large tooth–aligner contact surfaces so that the aligner could exert adequate force. The orthodontist must be able to identify the points or areas on the tooth crown where the aligner exerts pressure at each moment, modifying the way the tooth moves if these areas are small or create a lot of friction with adjacent teeth.

An example illustrating this is the mesio-distal root alignment of an upper central incisor (Figure 8). Since this is a tooth with a flat vestibular and palatal anatomy, and with minimal space on the mesial and distal sides (due to the presence of the contralateral central incisor and the lateral incisor), the only points of support for the plastic's push are the active surfaces of the optimized double root control attachment. As these are very small surfaces, the success of the root movement will be highly compromised. Adding an intrusive component to the lowermost end of the incisor while maintaining vertical height at the other end radically changes the region of the tooth where the aligner will push, increasing its push surface and, therefore, the success of the movement.

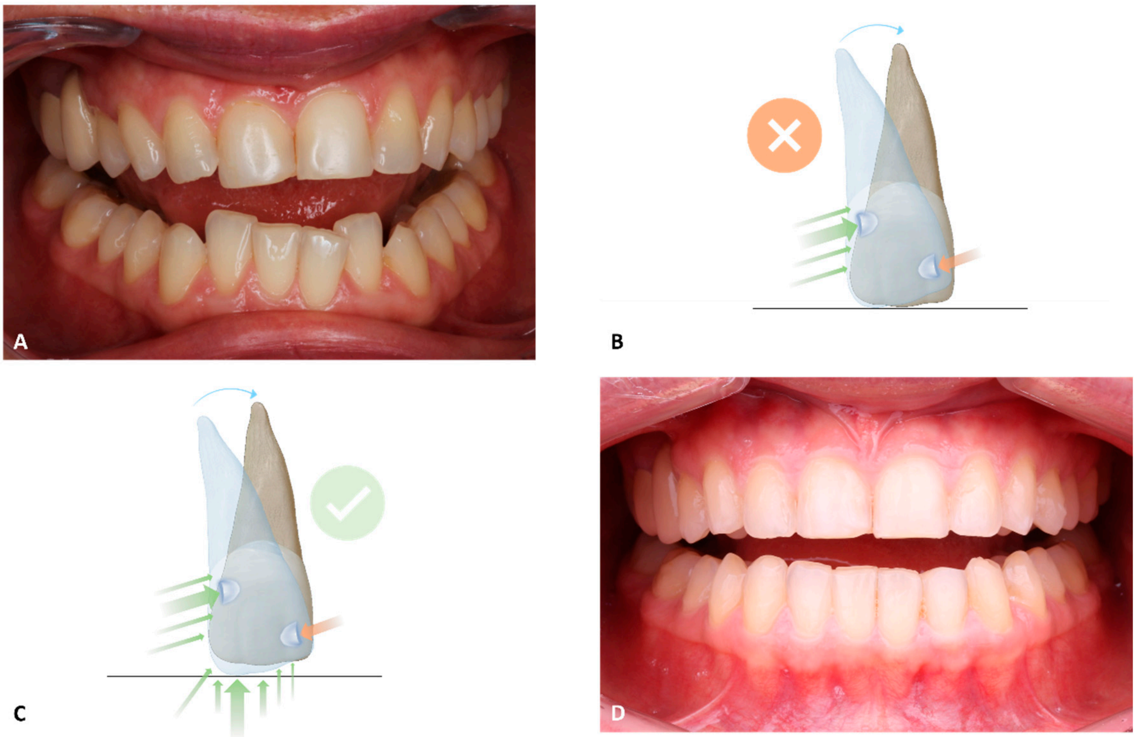

Figure 8. Upper-right central incisor with distal root inclination (**A**). Planning micro-staging where only mesial root alignment is performed has few support points for the plastic and depends on the active surfaces of the optimized attachments (**B**). Adding an intrusive component in the region of the more extruded incisal edge and maintaining the vertical position of the more intruded region (in this case, the mesial part) adds much more support surface to the plastic (**C**), achieving a more predictable root uprighting (**D**).

Rotational movements of round teeth also play an important role in this regard. Numerous authors have reported low predictability of success in this movement due to frequent loss of tracking [60,61]. We believe that this lack of effectiveness is associated with the way round teeth are derotated. On one hand, the anatomy of their surface makes it difficult to establish a perpendicular direction of forces in a pure rotation [61], depending on the active surface area of the attachment to support the aligner (again, a quite limited contact area) [15]. On the other hand, there is clear interproximal surface friction with adjacent teeth (which is detrimental in a closed system).

An interesting strategy is to change the type of planned rotation for a "*hinge*" movement, which incorporates a bucco-lingual component and places the center of rotation of the tooth at its mesial or distal contact point. Combining this type of rotation with an expansive or proclination movement (mesial-out or distal-out rotation) has two major advantages: (1) it adds a large portion of the palatal surface as a pushing surface and (2) it creates interproximal space, reducing friction. A study by Lione et al. [62], in which they combined expansion with mesial-out hinge rotation to derotate the upper first molars, achieved an 82% predictability. If the hinge rotation movement is performed inwards (mesial-in or distal-in rotation), it maintains the benefit of increasing the pushing surface compared to pure rotation (by extending the support area to a large part of the vestibular surface) but requires previously created space with interproximal teeth to avoid friction (presence of diastemas, interproximal reduction). In cases where a combination of outward and inward hinge movement is required, they can be combined in two stages, as shown in Figure 9. However, as of the publication date of this article, no studies have been published comparing the effectiveness of pure rotation versus hinge rotation, relying only on the clinical experience of the authors.

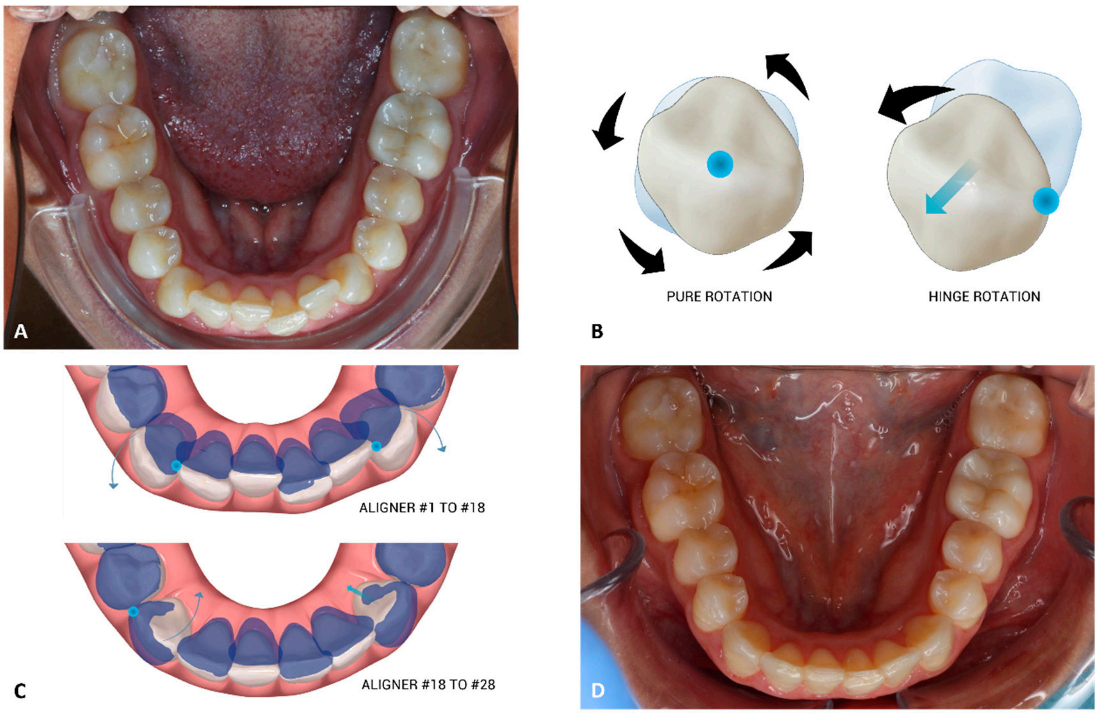

Figure 9. The lower canines exhibit rotations of their distal ends towards lingual, requiring a correction of 32° (tooth 33) and 46.5° (tooth 43) (**A**). Differences between the two derotation micro-staging, pure rotation with the center of rotation in the center of the tooth, and hinge rotation with the center of rotation at the mesial or distal point of the tooth (**B**). The micro-staging was divided into two phases, prioritizing an initial mesial-out hinge rotation of both canines, locating the center of rotation on their mesial face (aligner #1 to #18). Then, since tooth 33 had already completed its derotation but was over-expanded, lingualization was performed (one-time derotation). Tooth 43, on the other hand, required a second hinge rotation (mesial-in), centering its center of rotation on its distal face (two-time derotation) (**C**). Result of the first set of aligners with the lower canines completely aligned without requiring overcorrection of the rotational movement (**D**).

The creation of visible space between teeth seems to be an interesting way not only to reduce friction but also to improve plastic adaptability and decrease unwanted movements. A study by Cao et al. [63] demonstrated in vitro how planning small diastemas between anterior teeth reduced the bowing effect of the aligner caused by passive extrusive forces during anterior retraction in a case of first premolar extraction. Interdental spaces appear to be beneficial in cases of space closures as they increase the interproximal plastic surface and allow the aligner to access the mesial or distal aspects of target teeth, enhancing its pushing surface and system stiffness [56,57].

Observe Precontacts or Overlaps during Movement

Precontacts during movement, which at their maximum expression manifest as overlaps between teeth (the "*phantom tooth*" effect), can cause a problem during micro-staging. Clinically, we have observed that the amount of tooth overlap influences decision-making, with 1 to 3 mm considered an acceptable situation, as the increase in vertical dimension due to aligner thickness is usually sufficient to overcome the issue (with the patient being informed about the precontact stages to avoid strong chewing in the affected region). However, an overlap exceeding 3 mm can be uncomfortable for the patient and increases the risk of fracture or movement blockage, making alternative strategies worth considering.

A valid option could be to manipulate the movement speed in different arches to prevent the upper and lower teeth collision from coinciding simultaneously in the same stage. Other options include cementing permanent occlusal bite blocks and removing them once the contact has been uncrossed or intruding one of the teeth to reduce the overlap to less than 3 mm and then restoring its vertical height, as shown in Figure 10.

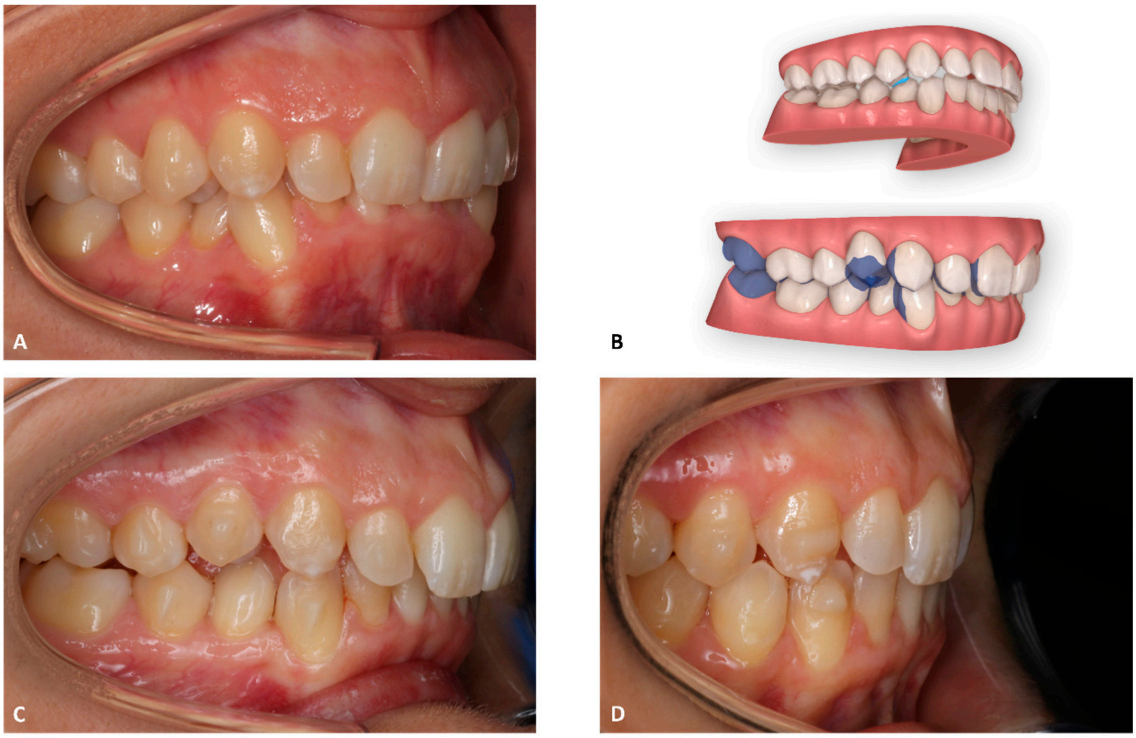

Figure 10. Right upper first premolar in scissor bite (**A**). In the original micro-staging developed by the CAD designer, there was an overlap of the right lower first premolar with the upper premolar, causing a "*phantom tooth*". The staging was modified to request the intrusion of 14 during the expansion of 44 and then its extrusion (**B**). Situation in aligner #9 with the intrusion of 14 (**C**). Result at the end of the first set of aligners (**D**).

Another relevant situation associated with precontacts occurs during the alignment of the lower anterior teeth. If the speed of the lower alignment (by buccal crown tipping) exceeds a minimum overjet of 1 mm, there is a risk of anterior precontacts, loss of tracking, and the development of a posterior open bite. This risk can be magnified if palatal root torque of the upper incisors is programmed and the movement is underexpressed, providing a false sense of security to the orthodontist during virtual planning. In these cases, we recommend maintaining a minimum overjet of 1 mm (measured from the palatal surface of the upper incisor to the buccal surface of the lower incisor) throughout the entire lower anterior micro-staging.

4.4. Limitations of the Study

The present review has methodological limitations due to its "narrative" purpose: the absence of scientific evidence on the topic of staging of the orthodontic tooth movement and clear aligners leads to a move away from a rigorous, systematic approach. This study seeks to satisfy the need for "ground knowledge" on this topic and to offer practical hints for developing further investigations. We hope that future lines of research will explore different staging approaches to address similar malocclusions to determine which are the most effective and applicable to clinical practice.

5. Conclusions

The staging of orthodontic tooth movement with clear aligners plays a crucial role in the success of the treatment as it is responsible for creating space (essential for a closed system), obtaining good pushing surfaces, and distributing anchorage. The division into macro-staging (general biomechanics) and micro-staging (individual biomechanics) allows the orthodontist to be more precise in observing the movement and reducing the accumulation of errors.

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