

Conceptual overcorrection in orthodontics: A strategy to enhance Invisalign's effectiveness

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Enhancing the predictability of demonstrated digital movements when using clear aligners is essential for achieving successful clinical outcomes. Commonly, fixed appliances require clinical methods of customization of prescriptions or perceived forces to enhance the biomechanical system needed to achieve more predictable outcomes. This paper aims to delve into this rationale, and perhaps necessity, of considering an overcorrection approach toward digital treatment planning of various movements with Invisalign clear aligners. Furthermore, specific suggestions are provided to serve as guidelines for clinical considerations and perhaps future research purposes to facilitate the increased predictability of Invisalign clear aligner outcomes. (Am J Orthod Dentofacial Orthop Clin Companion 2024;XX:XX-XX)



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Invisalign (Align Technology, Santa Clara, Calif) clear aligners have popularized clear aligner treatment in orthodontics, allowing for the design of a fully customized appliance modality to facilitate orthodontic treatment. Furthermore, usage of the appliance has steadily gained adoption in the resolution of increasingly challenging case types. Outside of excellent patient compli-

ance and a comprehensive diagnosis and treatment plan by the doctor, the success of Invisalign treatment largely relies on the proper customization of the appliance via digital treatment planning. This is conducted with ClinCheck (ClinCheck Pro 6.0; Align Technology) treatment planning software, which simulates a proposed outcome through 3-dimensional modeling. Recent publications have indicated the potential of

exaggerating software-generated movements to increase the predictability of clinical results, suggesting overcorrection of movements beyond what the software initially proposes.¹⁻⁴

Digital planning features that may directly affect the efficacy of clinical outcomes include alterations in the staging of movements, attachment design, and the intentional exaggerations of certain predicted movements.⁴⁻⁶ The combination of these considerations is intended to design a customized appliance that delivers the necessary force systems needed to achieve a desired outcome. However, the proper calibration of these features will fluctuate widely with regard to practitioner knowledge and experience. In this instance, experience should not be confused with the volume of patients one treats, but rather, their volition to improve their expertise with persistent learning, eventually separating digital hypothesis from clinical reality.

Experienced practitioners conjecture that Invisalign can be quite efficient and effective, but many studies claim otherwise. Often, these studies cite a lack of predictability of various movements and an overall inefficiency compared with fixed appliances.⁷⁻⁹ However, other papers disagree with the degree of these claims, whereas many orthodontic offices continue to provide and even grow their clear aligner offerings.¹⁰ So, why is there a lack of true specialty-wide consensus regarding the efficacy of clear aligners and their predictability?

One possibility is that this research may not adequately reflect what private practice orthodontists experience. As it stands today, there exists a notable variance of

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consistency regarding the reported accuracy of movements and outcomes. This may be attributed to poor sample sizes, heterogeneity of subjects, and variance in the methodologies tested.¹¹ In addition, proper detailing of a clear aligner treatment plan often involves refinements to comprehensively treat the patient, which are often missing from the current literature when measuring the overall efficacy of movements. With fixed appliances, doctors need to go through a series of wire changes, repositioning of brackets, or wire bends to achieve an ideal outcome. Comparatively, leaving out refinements in research findings eliminates the natural progression of comprehensive Invisalign treatment, which needs to be fully considered for proper research comparisons.

Furthermore, there is a lack of consideration in this research focused on the necessary nuances of digital treatment planning, which are required to achieve proper clinical outcomes. We cannot have a reasonable discussion of efficacy and accuracy until we treat the appliance as orthodontists and not as scientists. As orthodontic clinicians, we customize and exaggerate our fixed appliance force systems repeatedly. As a specialty that is steeped in the learnings of physics, it should come as no surprise that these same concepts need to routinely be applied to clear aligners as well. However, this type of nuanced apples-to-apples comparison rarely, if at all, takes place in the current literature as it stands.

THE RATIONALE FOR OVERCORRECTION OF DIGITAL MOVEMENTS

Overcorrection of digital movements refers to the intentional exaggeration of movements beyond what may initially seem necessary. Often, orthodontists will exaggerate specific movements in fixed appliances to ensure the best possible outcomes more efficiently. Examples of this include, but are not limited to, the following:

1. Overtreatment of a bracket prescription by altering the slot relative to the base to account for (1) manufacturing tolerances: metal slots need to be divergent at the opening to account for the removal of brackets from their mold, decreasing the accuracy for torque expression by creating “slop” in the slot. At times, wires also need to be subsequently adjusted to account for this issue by adding torque to the wire or by using stiffer wires for improvement of torque expression^{12,13} and (2) more favorable customized torque by flipping brackets upside down in various clinical situations, such as desiring increased buccal crown torque for lingually displaced incisors.
2. Tilting brackets off the long axis when bonding for overtreatment of root positioning into patients with extraction for improved root parallelism.

3. Positioning brackets into rotations is more than ideal to allow for improved resolution of the rotational correction.
4. Exaggeration of the force systems delivered via archwires by wiping in reverse curves of Spee or integrating multiloop edgewise mechanics.
5. Vertical elastics are used to facilitate the correction of vertical movements by applying more force to help level the curve of Spee at the buccal segments.

If it is common practice to enhance fixed appliances with such modifications, then why would the same logic not routinely apply to clear aligners? The reasons for digital overcorrection may vary from addressing known deficiencies of the appliance (ie, inadequate material properties) to facilitating an improvement of the patient’s biologic response.

The software should be used to “bend” the aligner, wherein then the aligner delivers an intended force system required to achieve a specific desired outcome. By knowing the appliances’ limitations and the patient’s biological challenges, the aligner requires individualized customization. The nuances of this will vary given the patient’s biological considerations, the treatment technique (ie, extractions, interproximal reduction, and elastics), type of malocclusion, overall individual tooth movements, and anchorage considerations.

Hence, the rationale for the exaggeration of certain digital movements assumes that Invisalign aligners cannot deliver the exact amount of movement predicted by the software. Conceptual overcorrection is the planning of more digital tooth movement than initially predicted in the software to achieve the desired clinical outcome. The premise of the digital treatment plan serving as a representation of a force system rather than an outcome further helps to facilitate this notion. This concept is especially important in the patient’s first set of aligners, which should serve to address major treatment goals and challenging movements (eg, bite opening with anterior intrusion, anterior lingual root torque expression, or significant root movements). The refinement sets, assuming major goals have been accomplished, should then ideally serve to fine-tune and detail.

EXAMPLES OF DIGITAL OVERCORRECTION

1. Digital exaggeration of proposed movements: exaggeration of specific movements within the software that are known from studies or clinical experience to underperform relative to software predictions. Digital overcorrection is performed to account for anticipated material property deficiencies, challenging individual tooth movements, or a specific patient biologic response to orthodontic forces. To elaborate,

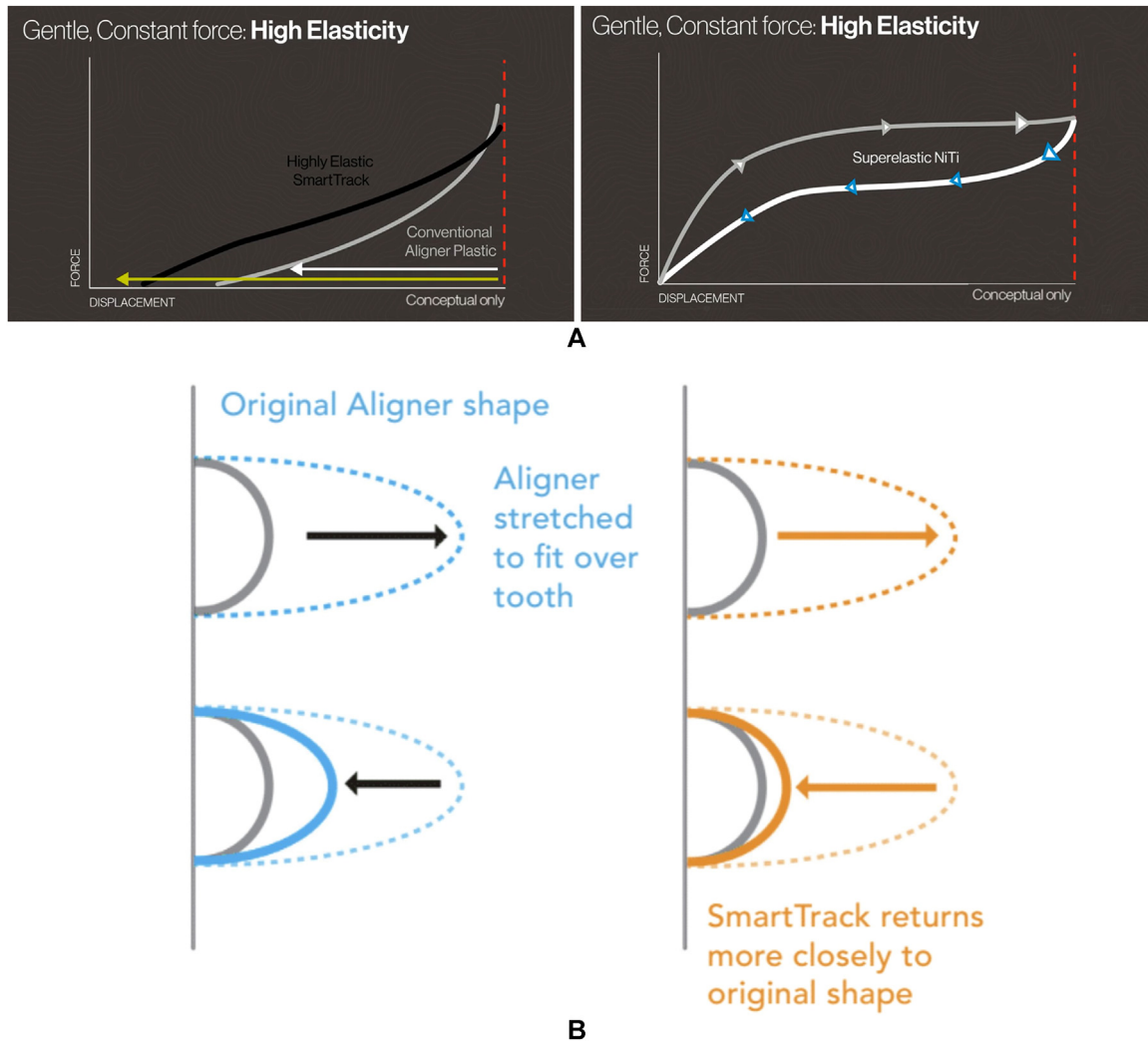


Fig 1. A, SmartTrack was developed for Invisalign treatment and is made from a multilayer aromatic thermoplastic polyurethane. This material has been reported to maintain a more constant force over time, much like a nitinol wire, which then could express more tooth movement over a longer period vs conventional aligner plastics (reproduced with permission from Align Technology, the producers of Invisalign); **B**, Illustration demonstrating that SmartTrack aligners return more closely to their original shape vs Align's previous EX30 plastic (from Morton J, Derakhshan M, Kaza S, Li C. Design of the Invisalign system performance. *Semin Orthod* 2017;23:3-11).

consider the analogy that aligners have properties akin to a rectangular nickel-titanium wire (Fig 1). If this is the case, then certain adjustments may need to be made when determining the type of force system delivered. With experience, orthodontists should recognize when biological responses to certain simulated movements may be limited because of this material property trait. To address this, the exaggeration of tooth movements in the simulation to compensate for the anticipated lack of biological response is required.

2. Extended treatment duration: the extension of the treatment time beyond what is initially planned or estimated by the software. Extended treatment duration can allow for more expression of tooth movements, as

certain movements may lag what the staging may anticipate. This may be done by extending wear time beyond the recommended 1-week interval or by altering the staging (amount of designed tooth movement allowed per aligner) of tooth movement, which often adds aligners and extends treatment time.

Of note, pursuant to the release of their 2016 seventh-generation improvements, Align Technology recommended weekly changes of aligners for patients with mild to moderate malocclusion only. It was noted that the decision for weekly changes must be individualized, depending on the complexity of the patient's condition and the age of the patient. Many times, practitioners may not heed this fine print and attempt weekly changes for all malocclusions, which may lead to clinical fit issues (Fig 2).

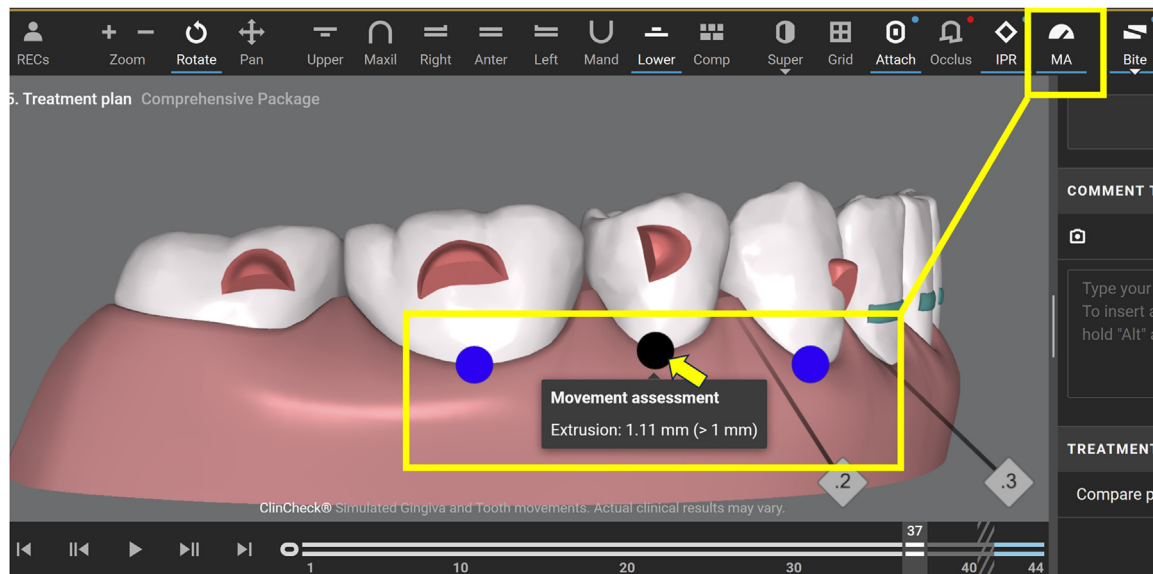


Fig 2. The decision to prescribe weekly aligner changes is at the doctor's discretion. Doctors need to monitor and make this decision based specifically on the degree of tooth movements, such as rotations, extrusions, and significant root movements, particularly blue and black movements, in the Tooth Movement Assessment tool. Depending on the degree of more challenging movements and the patient's response to treatment—particularly mature adults—longer periods between aligner changes may need to be considered (reproduced with permission from Align Technology, the producers of Invisalign).

3. Altered staging: staging refers to either the order of tooth movement or the rate of tooth movement within the software. Alterations of staging have a substantial influence on treatment outcomes and predictability by altering the force levels instigated by the plastic, overall anchorage preparation, or slowing down more challenging movements.^{14,15}

SPECIFIC MOVEMENT CONSIDERATIONS FOR OVERTREATMENT

The following suggestions are based on the lack of predicted expression of various movements reported in the current literature, combined with the author's clinical experience. Recommendations are provided on the basis of singular tooth movements only. If multiple orders of movement are occurring simultaneously for a particular tooth, then appropriate consideration should be given to the more challenging movement. More high-quality research is needed to confirm the following suggestions. Furthermore, it should be assumed that refinements will be needed in most treatment plans to properly detail the occlusion.¹⁶

Tipping is considered the most predictable movement with aligners.¹⁷ However, there are unintended clinical consequences to this type of movement. Tipping to the labial leads to an intrusive clinical side effect of incisors (Fig 3), and lingual tipping leads to an extrusive/bite-deepening side effect at the incisors. These side effects can be antagonistic or synergistic to certain clinical goals (bite

opening or bite closure) and need to be considered when designing force systems and attachments.

Although the movement may not express 100%, it is generally deemed the most predictable movement within an aligner system. Overtreatment of tipping is not recommended; any discrepancies should be addressed in a refinement.

Clear aligners can induce controlled root movements by applying forces through various means, particularly on aligner attachments or available contrasting surfaces (occlusal or interproximal). The force required for root movement is highly dependent on the tooth, its position, and the desired outcome. As aligners push teeth occlusal to their center of resistance, the tendency is for root movement to fall behind the movement of the crown, especially if bodily movement is attempted.^{18,19}

Attachments are necessary and allow for an improvement in the predictability of root movements.^{20,21} Of note, with Invisalign, root control attachments do not have automation for placement on molars or mandibular incisors. Hence, conventional attachments will need to be placed by the doctor to facilitate root movements of these teeth (Fig 4).

Overcorrection of root movement may come in the form of virtual gable bends within the software or a change in staging to allow for visible spaces around the teeth that need root movement to provide a full interproximal wrap of plastic, which may add stages and extend treatment time.²² The author recommends adding a 5°-10° root tip beyond what is proposed for proper clinical expression of

root movements, especially when opening spaces for implants or closing extraction sites (Fig 5). Furthermore, tray changes may need to be extended to ensure proper expression of this movement on the basis of the proper fit of the aligner.

As mentioned, with regard to tipping movements, intrusion of incisors during proclination will occur more predictably. If occurring during retraction, the movement will be more challenging. Regardless, overall intrusion falls short of the predicted digital demonstration.²³⁻²⁵

Intrusion, both anterior and posterior, will benefit from exaggeration of the digital movement. Generally, the tooth intruding does not require an attachment, as the aligner can push on the incisal/occlusal portion of the crown to facilitate the movement. However, anchorage is needed on the adjacent teeth to capture the equal and opposite extrusive force.²⁶ This is important, as the movement will increasingly fail without proper anchorage from adjacent teeth. The amount of digital overcorrection of intrusion will depend on (1) antagonistic vs synergistic movements (ie, an anterior intrusion is more predictable during proclination but needs more exaggeration during retraction or lingual movement of the incisors). Hence, patients with crowding will have more predictable intrusion, whereas patients with spacing closure will experience less predictable bite opening and will require substantially more overtreatment of their digital movements; and (2) biologic considerations (ie, patients with brachycephaly will require more overtreatment than those with dolichocephaly; growing adolescents will need less overtreatment vs adults because of a growth-related compensatory eruption of their posterior dentition, among other relevant considerations).

In general, overcorrection beyond the initial overall digital movement shown should be increased by 50%-100% of the total amount of the initial ideal outcome predicted on the basis of consideration of the variables above. This means if one considers the ideal overbite to be 2 mm, then overtreatment should range from a proposed finish of 0 mm overbite to -2 mm overbite, and possibly even more, depending on individual circumstances.

Traditionally, aligners were considered poor at performing extrusive movements. However, with a better understanding of aligner biomechanics, extrusion can now be achieved more predictably.²⁷ Extrusion, when done anteriorly, may not benefit from overtreatment, as it tends to perform acceptably well with good compliance, especially when combined with overall lingual movement of the incisors simultaneously.²⁸

However, absolute extrusion down the long axis of teeth is quite unpredictable. Overtreatment is still not recommended, as this will likely make matters worse. Often, the lack of expression of extrusion down the long axis results from the inability of the aligner to purchase the tooth properly during treatment. In these circumstances, in which

extrusion down the long axis is required either anterior or posteriorly, fixed appliances or elastic auxiliaries are likely required.

Another consideration is that teeth with poor anatomy, such as small lateral incisors, should not have extrusion attempted with an aligner and would perhaps benefit from restorative options instead. Often, if the practitioners' clinical preferences call for level incisal edges, this may be overlooked and lead to clinical aligner fit issues as a result.

Rotational movements require a couple of moments to rotate the tooth along the long axis. Clear aligners achieve this by incorporating carefully designed attachments or pressure areas to apply localized forces. Most mild rotations achieve acceptable resolution when proper attachments and staging have been considered. Predictability may deviate from ideal when rotations are $>15^\circ$.²⁹

Rotational efficacy will also vary depending on the type of tooth being rotated. Rotation of the first molars is a movement with excellent predictability.³⁰ Conversely, rotational movements of the maxillary lateral incisors, or canines and premolars in general, will be increasingly difficult to control with aligners.^{3,31}

Teeth rotating will require attachments, especially if conically shaped or tapered, to have an improved chance at predictability. Attachments serve not only as a push surface toward the direction of intended movement but also as a means of retention. Teeth rotating in an aligner experience an intrusive tendency as they are squeezed apically from the sum of the forces acting on the tooth because of the general convergence of overall dental anatomy. Hence, attachments also concomitantly serve as an additional undercut, providing retention to mitigate the side effect of this intrusive tendency.

Software automation for attachment decisions may provide specific rotational attachments when the movement is prioritized within the decision hierarchy for automated attachment placement. However, if other complex movements exist, such as root movement, then the attachment provided may not account for the multiorder demands of both movements simultaneously. In these circumstances, a change in the type of attachment, or possibly the staging of the movements to separate them, may be indicated to improve predictability.

Overall, the reported consensus is that the accuracy of the rotational corrections is poor. To overcome this issue, it is suggested that the rotated teeth be overcorrected by 5° beyond the ideal position.⁴ Slowing down the rotational movement to about 1° per aligner tray when staging can also allow for better rotational correction, as it has been shown in previous studies that increasing the amount of rotational movement to $>1.5^\circ$ per aligner tray leads to decreased accuracy.¹⁶

When considering exaggeration of the movement, overcorrection may be added either through the duration of

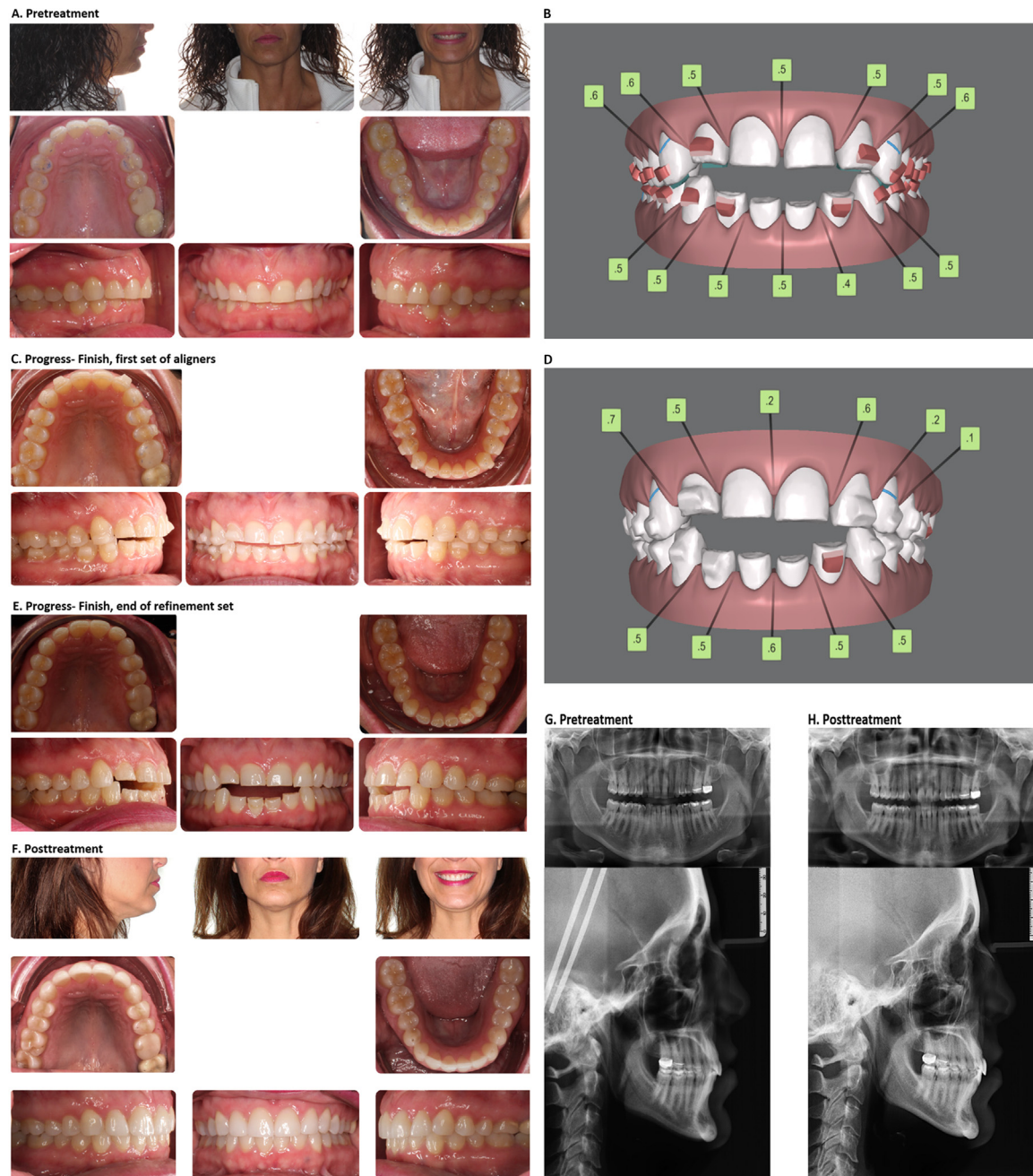


Fig 3. **A**, Intraoral photographs of an adult female patient presenting with a Class I deepbite malocclusion with significant anterior wear. Her treatment plan involved bite opening with Invisalign to plan for future restorative treatment to address the incisal edge wear; **B**, Final stage of the initial ClinCheck, demonstrating significant overtreatment of anterior intrusion via mainly proclination with subsequent bite opening. Considering the clinical tendency of intrusion to fall short of what is predicted, the need for digital overtreatment of the movement is shown here. A total of 70 aligners were needed to achieve the predicted outcome. However, the patient made it through 60 before scanning for refinement aligners at the end of 13 months to produce more well-adapted aligners after interproximal spacing became present through treatment progress; **C**, Intraoral photographs showing the end of the first set of aligners, demonstrating successful bite opening, but short of the predicted ClinCheck outcome; **D**, Final stage of refinement ClinCheck, continuing to open the bite for future restorative work. An additional 40 aligners were needed to finish the treatment, for a total treatment time of 23 months (reproduced with permission from Align Technology, the producers of Invisalign); **E**, Final photographs before restorative work; **F**, Posttreatment records after restorative completion; **G**, Pretreatment radiographs; **H**, Posttreatment radiographs.

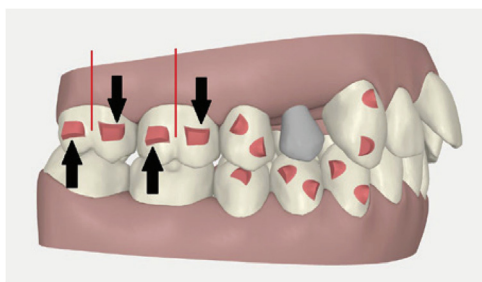


Fig 4. The representation of twin molar root control attachments on the maxillary right first and second molars was added manually because automation for root control attachments does not currently exist in the software. The push surfaces are oriented in opposite directions on each attachment to allow for the mesial root tip to facilitate improved bodily movement of the molars because of maxillary premolar extraction (Nicozisis J. The Yin-yang attachment: the clear path to molar zen. *The Progressive Orthodontist*. Available at: <https://princetonorthodontics.net/wp-content/uploads/2019/05/Nicozisis-Ying-Yang-Final.pdf>. Accessed May 11, 2024).

treatment or at the tail end of treatment in the form of overcorrection aligners to provide individual incremental overcorrections on a tooth-by-tooth basis. Theoretically, staging the additional overcorrection of rotations toward the end of the treatment may allow for other more predictable movements to be achieved first.

In addition, the higher the degree of rotation of the tooth, the harder it is to achieve complete rotational correction.^{7,16} At times, for very challenging rotations, couples may be needed with elastics and buttons bonded to the teeth to facilitate further correction.

For movements that involve torque, Invisalign automatically provides the use of Power Ridges anteriorly for lingual root torque of incisors or G8 SmartForce Features for premolars and first molars for buccal root torque (Fig 6) posteriorly. Conversely, for buccal root torque anteriorly or lingual root torque posteriorly, the practitioner needs to design the force system with supporting attachments as needed to facilitate the correction of these specific movements.

It has been reported that the accuracy for the torquing movements with aligners may range from 49%-73%, with the culmination of studies averaging around 50%¹⁶. In general, it has been reported that lingual/palatal crown torque has better expression than labial crown torque for maxillary incisors. Furthermore, it has been reported that overall mandibular incisor torque expression is superior compared with maxillary incisor torque expression.³² Overall, torque is a complicated movement with clear aligners, which requires exaggeration, akin to fixed appliances in which torque is either exaggerated in the bracket or our wires.

Power Ridge features may be automatically placed by the software to enhance the expression of anterior lingual root torque. However, it should be noted that because of

the couple generation from the feature, Power Ridges may lead to some fit issues of the aligners, especially if rotation or any extrusion of the teeth is noted as well (Fig 6, A). Hence, horizontal gingivally beveled attachments may provide for better retention of the aligner anteriorly when torque is desired. As with intrusion, torque is more difficult to attain when there is overall retraction of the dentition, and more overtreatment of the movement is required when the lingual movement of the incisors is noted.

It is recommended by the author to consider doubling the amount of torque a practitioner wishes to achieve as a goal on the basis of their cephalometric analysis up to 15°, especially for the maxillary incisors. If >15° of torque is needed, then it is recommended to add 15° overall. For example, if 5° is desired, ask for 10°. If 20° is desired, ask for 35°. In addition, similar to complex rotations, it is recommended to stage 1° of torque expression per aligner only. Patients should only change their trays when they visually fit, as otherwise, patients often try to stick to a routine vs changing when they are truly ready. For adults especially, this may mean staying in the aligner for >1 week.

For canines and posterior teeth, a buccal attachment is needed for proper expression of buccal root torque, allowing for a push surface to create the moment required around the root apex. Automation for the appropriate attachments and SmartForce Features of G8 will not trigger unless 0.5 mm of expansion is noted by the software and appropriate crown anatomy is available (Fig 6, B). If conditions and thresholds are not met by the software, the clinician should build in the appropriate attachment designs and add extra buccal root torque to create the appropriate force system. Buccal root torque will be more challenging during expansion because of the countermoment from buccal crown tipping from labial movement, and conversely, it will be more predictable during constriction of the arches.

Pure translation is not feasible with aligners without the use of power arm auxiliaries to apply forces through the center of resistance. However, most practitioners depend solely on the aligners to achieve bodily type movements. Several studies have indicated that space closure with aligners only will generally lead to more crown than root tip, especially when closing extraction sites.^{33,34} However, with proper setup of anchorage tip backs of teeth distal to the extraction site, attachment planning, use of segmented staging, and purposeful digital overtreatment of certain movements, bodily type movements will become increasingly predictable with aligners.³⁵ The degree of digital exaggeration needed will depend on the type of translational movement desired on the basis of distalization vs. space opening vs. space closure.

Simon et al¹⁶ reported 87% accuracy for molar distalization of >1.5 mm on maxillary molars without using Class II elastics for anchorage in a 2016 multicenter study.

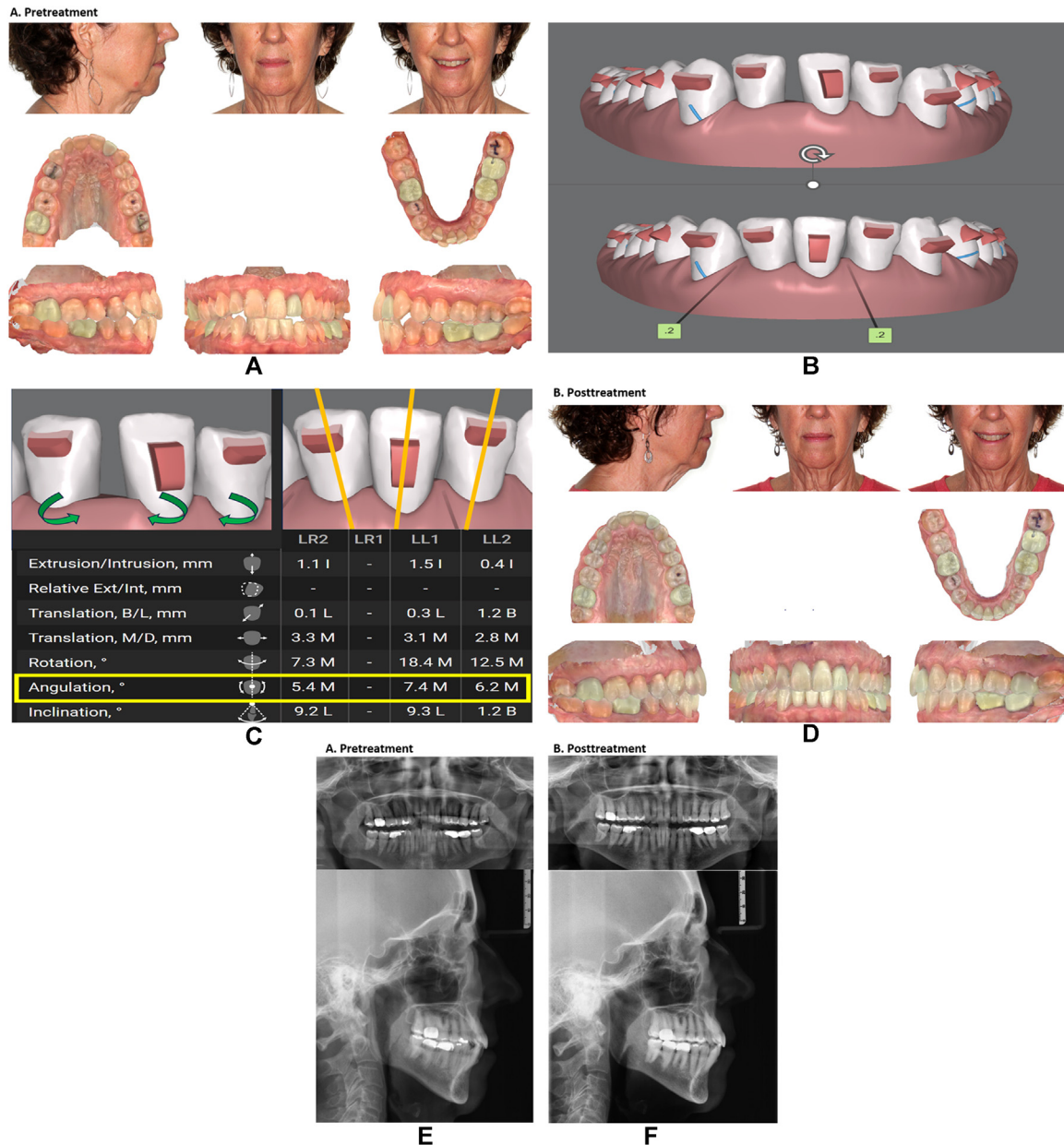


Fig 5. **A**, Intraoral photographs of an adult female patient presenting with a Class I malocclusion with significant mandibular anterior crowding and a lack of overjet. Her treatment plan involved extraction of the mandibular right central incisors with Invisalign to comprehensively treat her condition; **B**, Juxtaposition of initial vs final stages of the first ClinCheck plan, demonstrating a virtual gable bend between the mandibular left central incisor and mandibular right lateral incisor to overtreat root control while closing the extraction site of the mandibular right central incisor. A purposeful space was also left on the distal of these teeth for a better approximation of interproximal plastic and increased push surfaces to control the roots during closure (reproduced with permission from Align Technology, the producers of Invisalign); **C**, Illustration demonstrating mesial root tip of all incisors, with overtreatment ranging 5°-7° (reproduced with permission from Align Technology, the producers of Invisalign); **D**, Posttreatment records. The patient completed treatment after 1 set of aligners only, comprising 60 total aligners; **E**, Pretreatment radiographs; **F**, Posttreatment radiographs.

Ravera et al³⁶ analyzed the effective amount of distalization with clear aligner therapy in nongrowing patients, in which distalization was 2.25 mm for the first molar and 2.52 mm for the second molar when vertical rectangular attachments were planned. Similar results were shown in the study conducted by Garino et al.,³⁷ with 2 mm of distalization accompanied by 1 mm of intrusion. With these studies,

attachment designs and staging were considered important to success. Hence, on the basis of the overall predictability of the movement, overtreatment is not recommended, but greater than 2 mm of movement should not be expected.^{16,37,38} A potential reason for the improved predictability of this movement may amount to the fact that maxillary distalization often amounts to tipping the

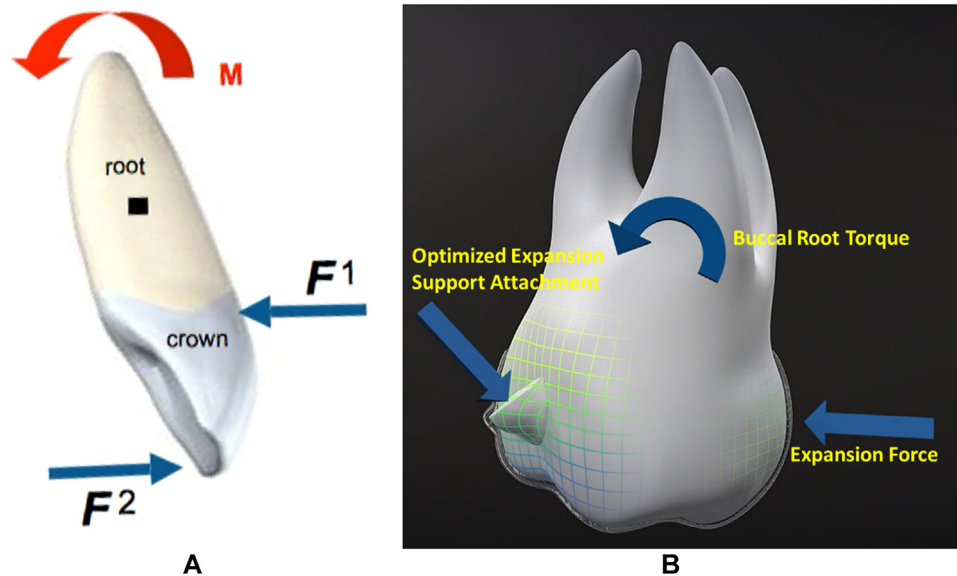


Fig 6. A, Illustration of the Power Ridge feature to elicit lingual root torque with Invisalign (reproduced with permission from Align Technology, the producers of Invisalign); **B,** Illustration of the SmartForce Features associated with Invisalign to facilitate a force system for buccal root torque during arch development for a first molar (reproduced with permission from Align Technology, the producers of Invisalign).

crowns under the roots, as many Class II malocclusions have a mesial anchorage loss over time. This is evidenced by the fact that 80% of patients with Class II malocclusions have maxillary molars rotated mesially. In contrast, mandibular distalization is not well reported in the literature. Anecdotally, this movement is considerably less predictable than maxillary distalization and should be used on a selective case-by-case basis in which the movement would seem more favorable, such as in the recent third molar extraction.

When space opening involves opening a room from the collapse of interdental space caused by crowns tipping/converging into space, then uprighting the crowns over the roots should be predictable, as this would be considered a tipping movement vs a bodily movement. However, if the roots need to move apart as well to open room from loss of interradicular spacing, then 5°-10° of overtreatment of the root positions is indicated, as pushing occlusal to the center of resistance makes this movement more challenging. Furthermore, this movement may often need a slower rate of tray changes, again only changing the aligner when it fits properly. Finally, staging for a full wrap of plastic around the teeth needing root movement allows for more predictable root movement, as does the use of vertical or root control attachments.

Overtreatment techniques here would be to offset the tendency of the crown to move ahead of the root and mitigate side effects that would cause the curve of Spee to steepen. This involves performing virtual gable bends of the roots moving into the space, along with the recommendation of segmenting staging to allow for

a full wrap of plastic around the teeth moving into space.

Common side effects of space closure involve greater mesial tipping at the molars. At the incisors, greater extrusion and greater lingual crown torque are seen clinically as a side effect of the inability of the aligner to level the curve of Spee. “Dumping” of the buccal segment may also often occur from this overall loss of control of the curve of Spee.³⁹ Anchorage preparation is recommended to proactively mitigate the anticipated negative tooth movements. Mesial root tip/distal crown tipping of the first molars with root control attachments should be prescribed to maintain normal angulation and attempted bodily tooth movement. Segmented staging for space closure of premolar extractions is recommended, as described later. Overtreatment of anterior intrusion and anterior lingual root torque, along with appropriate supporting attachments, should be planned in the software to mitigate the steepening of the curve of Spee.

Current studies indicate worsening outcomes for expansion moving from the canine areas toward the distal portions of the aligners to the molars.^{36,37,40} The mechanical behavior of the distal portion of an aligner shares similarities to traditional fixed appliances, in which a decreased amount of force is exerted by the end of the archwire as the interbracket distance and the flexibility of the wire increase. Henceforth, lower forces toward the molars could result in less accurate movement with aligners in this area as well.³

Furthermore, it has been reported that the mean accuracy of buccal transverse expansion in the maxillary arch

was 75%, whereas the mean accuracy of buccal expansion in the mandibular arch was greater at 87% molars.⁴¹⁻⁴⁴ This may be due to the skeletal etiology of the clinical presentation of arch constriction. Often, the mandibular dentition tips lingually to compensate for skeletal transverse deficiencies. Hence, the correction of the mandibular arch development movements is more likely controlled tipping movements without resistance, whereas in the narrow maxilla, in which the teeth are already upright over basal bone, expansion of the arch will likely meet resistance with the buccal cortical plate leading to uncontrolled tipping with consequent intrusion of the buccal cusp and plunging of the palatal cusps. Hence, overcorrection recommendations based on expansion inaccuracies must be considered cautiously, taking dentoalveolar relationships into account.

Given that the aligner appears to have less efficacy toward the terminal tooth, crossbite elastics may be required to obtain a better transverse tooth relationships in the molar areas. Overcorrection of maxillary arch expansion is recommended to be prescribed into the digital plan for predictable bodily movement, especially in the posterior region, by 1-2 mm of increased buccal overjet. Moreover, appropriate attachments for buccal root torque are important for better bodily movement control during arch expansion.⁴⁵ As with any buccal or labial movements, the periodontal status must be taken into careful consideration.

STAGING CONSIDERATIONS

Staging refers to the sequence and velocity in which the teeth are moved with aligners. Once the initial and the desired final positions of the teeth are determined, corrective paths are devised between the 2.⁴⁶ When setting up a treatment plan in the ClinCheck software, staging is of particular importance in obtaining acceptable clinical predictability.⁴⁷ For example, it is challenging mechanically to accomplish different tooth movements in several planes of space at the same time. Conversely, staging the tooth movements in separate planes of space is considered more clinically predictable. This is an important concept because the software automatically stages simultaneous tooth movement by default.^{47,48} Although not deemed as overcorrection per se, staging does, in many patients, extend treatment time, which is a form of overcorrection in that what is predicted initially by the software may not offer enough treatment time for predictable clinical expression of movements. Hence, stages may need to be added to allow for the proper expression of outcomes. Examples of staging are as follows:

1. Simultaneous staging, in which all the teeth of an arch are moved together from the initial to the final stage. This type of staging may have a negative effect on

complex tooth movements or arch leveling, especially when space closure is needed.

2. Segmented staging, in which 1 small group of teeth is moved, whereas another group is kept stationary to improve or provide anchorage. This type of staging may be preferred in complex malocclusions, especially ones that involve space closure. Examples of this staging include (1) V-staging, which refers to the distalization of the molars first, followed by premolars, and ends with the retraction of anterior teeth; (2) A-staging, which is the opposite of V-staging and is characterized by the movement of the anterior teeth in the anterior direction, followed by the posterior teeth; (3) Frog-staging, which is used in patients with extraction for improved bodily control. This staging also increases the number of aligners, which may allow for less bowing of the buccal segments as the aligner has more time to level the curve of Spee, allowing for fewer side effects such as anterior extrusion and increased lingual crown torque. This staggered staging technique features the canines retracted first for a series of stages, together with some mesialization of the molars, and then a pause/rest period. Then, the incisors are retracted for a series of stages and then stopped. The canine movement is restarted for another several stages, and stopped, followed by further incisor retraction. This pattern is repeated until the extraction spaces are closed and the incisors fully retracted⁴⁹; and (4) G6 staging, which is automated segmented staging from Align Technology, either for maximum or moderate anchorage of premolar extraction site space closure. Specific SmartForce Features with staging and attachment designs are automated and implemented.

CONCLUSIONS

Conceptual overcorrection of digital movements is a strategy to enhance the effectiveness of Invisalign outcomes by planning more tooth movement than the proposed digital outcome or by altered staging to allow for increased treatment time or an improvement of biomechanics. Inherent to the suggestion of digital overcorrections is the message that doctors need to make modifications to the digital treatment plan for ideal outcomes (Table). Accepting what is given by the manufacturer solely will lead to outcomes that may not serve the best interest of the patient or provide the intended goal of treatment.⁵⁰ By “doctoring” the digital treatment plan, digital overcorrections can help to overcome some of the limitations and challenges of Invisalign treatment, such as complex or multidimensional tooth movements, aligner material inefficiency, or differences in patient biologic responses to treatment. Digital overcorrections should be

Table. A summary of overtreatment recommendations described in this article, with associated considerations

<i>Movement</i>	<i>Overtreatment recommended</i>	<i>Other considerations</i>	<i>Attachment considerations</i>
Tipping	None	May lead to unintended consequences (ie, the intrusive tendency during labial tipping)	Only if combined with other movements or anchorage needs
Intrusion	50%-100% Of the total ideal movement predicted	More predictable during labial movement for incisors, more challenging during lingual movement of incisors	Required on the adjacent teeth for anchorage
Extrusion	None anteriorly; posterior only when adding reverse curve mechanics	More predictable during lingual movement, less during labial movement or down the long axis (may need elastics to finish)	Either optimized or conventional beveled attachments needed
Rotation	5° Additional correction	Decreases in predictability if >15° needed total, may need auxiliaries	Either optimized or conventional needed
Root movement	5°-10° Additional correction	May benefit from the interproximal wrap of plastic and segmented staging	Either optimized or conventional needed
Torque	Double up to 15°; after that add an additional 15°	May need more time than 1 wk; no more than 1° per aligner recommended	Horizontal beveled attachment when Power Ridge feature not used
Expansion	1-2 mm, Increasing more toward molars	Skeletal etiologies and limitations need to be considered carefully	Recommended, especially when buccal root torque desired

based on experiential judgment and must be closely monitored clinically.

Ideally, the exaggeration of digital movements should be supported by evidence-based research and guidelines, which are currently scarce and inconsistent. Therefore, more high-quality studies are needed to evaluate the efficacy, safety, and long-term effects of overtreatment of proposed movements with Invisalign treatment. Ultimately, it should be accepted that full resolution of any malocclusion rarely occurs in 1 set of aligners only. Digital overcorrection strategies should be targeted to achieve major movements in the first set of aligners. Refinements should be accepted as a part of the treatment plan, rather than a failure or lack of efficacy, and used to detail movements that did not express 100% in the first set.

CONFLICTS OF INTEREST

The author of this article is a consultant for Align Technology.

STATEMENT OF INFORMED CONSENT

Informed consent was obtained from the patients and/or legal guardians regarding all patients shown in this submission.

REFERENCES

1. Kravitz ND, Moshiri M, Nicozisis J, Miller S. Mechanical considerations for deep-bite correction with aligners. *Semin Orthod* 2020;26:134-8.
2. Liu L, Song Q, Zhou J, Kuang Q, Yan X, Zhang X, et al. The effects of aligner overtreatment on torque control and intrusion of incisors for anterior retraction with clear aligners: a finite-element study. *Am J Orthod Dentofacial Orthop* 2022;162:33-41.
3. Castroflorio T, Sedran A, Parrini S, Garino F, Reverdito M, Capuozzo R, et al. Correction to: predictability of orthodontic tooth movement with aligners: effect of treatment design. *Prog Orthod* 2023;24:47.
4. Mehta S, Patel D, Yadav S. Staging orthodontic aligners for complex orthodontic tooth movement. *Turk J Orthod* 2021;34:202-6.
5. Nucera R, Dolci C, Bellocchio AM, Costa S, Barbera S, Rustico L, et al. Effects of composite attachments on

- orthodontic clear aligners therapy: a systematic review. *Materials (Basel)* 2022;15:533.
6. Jedliński M, Mazur M, Greco M, Belfus J, Grocholewicz K, Janiszewska-Olszowska J. Attachments for the orthodontic aligner treatment-state of the art-A comprehensive systematic review. *Int J Environ Res Public Health* 2023;20:4481.
 7. Haouili N, Kravitz ND, Vaid NR, Ferguson DJ, Makki L. Has Invisalign improved? a prospective follow-up study on the efficacy of tooth movement with Invisalign. *Am J Orthod Dentofacial Orthop* 2020;158:420-5.
 8. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. *Angle Orthod* 2015;85:881-9.
 9. Weir T. Clear aligners in orthodontic treatment. *Aust Dent J* 2017;62:58-62.
 10. Bilello G, Fazio M, Amato E, Crivello L, Galvano A, Currò G. Accuracy evaluation of orthodontic movements with aligners: a prospective observational study. *Prog Orthod* 2022;23:12.
 11. Jaber ST, Hajeer MY, Sultan K. Treatment effectiveness of clear aligners in correcting complicated and severe malocclusion cases compared to fixed orthodontic appliances: a systematic review. *Cureus* 2023;15:e38311.
 12. Lee Y, Lee DY, Kim YJR. Dimensional accuracy of ceramic self-ligating brackets and estimates of theoretical torsional play. *Angle Orthod* 2016;86:804-9.
 13. Silver M, Griffin AC Jr, Azzopardi L, Masoud MI, Tokede O, Griffin AC 3rd. Novel methods reveal that parallelism contributes to the functional vertical slot dimension in ceramic and metal brackets. *Angle Orthod* 2018;88:812-8.
 14. Al-Nadawi M, Kravitz ND, Hansa I, Makki L, Ferguson DJ, Vaid NR. Effect of clear aligner wear protocol on the efficacy of tooth movement. *Angle Orthod* 2021;91:157-63.
 15. Yao S, Jiang W, Wang C, He Y, Wang C, Huang L. Improvements of tooth movement efficiency and torque control in expanding the arch with clear aligners: a finite element analysis. *Front Bioeng Biotechnol* 2023;11:1120535.
 16. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Treatment outcome and efficacy of an aligner technique—regarding incisor torque, premolar derotation and molar distalization. *BMC Oral Health* 2014;14:68.
 17. Muro MP, Caracciolo ACA, Patel MP, Feres MFN, Roscoe MG. Effectiveness and predictability of treatment with clear orthodontic aligners: a scoping review. *Int Orthod* 2023;21:100755.
 18. Yokoi Y, Arai A, Kawamura J, Uozumi T, Usui Y, Okafuji N. Effects of attachment of plastic aligner in closing of Diastema of maxillary dentition by finite element method. *J Healthc Eng* 2019;2019:1075097.
 19. Pavoni C, Lione R, Laganà G, Cozza P. Self-ligating versus Invisalign: analysis of dento-alveolar effects. *Ann Stomatol (Roma)* 2011;2:23-7.
 20. Smith JM, Weir T, Kaang A, Farella M. Predictability of lower incisor tip using clear aligner therapy. *Prog Orthod* 2022;23:37.
 21. Ren L, Liu L, Wu Z, Shan D, Pu L, Gao Y, et al. The predictability of orthodontic tooth movements through clear aligner among first-premolar extraction patients: a multi-variate analysis. *Prog Orthod* 2022;23:52.
 22. Chan E, Darendeliler MA. The Invisalign® appliance today: a thinking person's orthodontic appliance. *Semin Orthod* 2017;23:12-64.
 23. Blundell HL, Weir T, Kerr B, Freer E. Predictability of overbite control with the Invisalign appliance. *Am J Orthod Dentofacial Orthop* 2021;160:725-31.
 24. Goh S, Dreyer C, Weir T. The predictability of the mandibular curve of Spee leveling with the Invisalign appliance. *Am J Orthod Dentofacial Orthop* 2022;162:193-200.
 25. Shahabuddin N, Kang J, Jeon HH. Predictability of the deep overbite correction using clear aligners. *Am J Orthod Dentofacial Orthop* 2023;163:793-801.
 26. Moshiri M, Kravitz ND, Nicozisis J, Miller S. Invisalign eighth-generation features for deep-bite correction and posterior arch expansion. *Semin Orthod* 2021;27:175-8.
 27. Burashed H. The efficacy of anterior open bite closure when using Invisalign's optimized extrusion versus conventional attachments. *J World Fed Orthod* 2023;12:112-7.
 28. Meade MJ, Blundell H, Weir T. Predicted overbite and overjet changes with the Invisalign appliance: a validation study. *Angle Orthod* 2023;94:10-6.
 29. Koletsi D, Iliadi A, Eliades T. Predictability of rotational tooth movement with orthodontic aligners comparing software-based and achieved data: a systematic review and meta-analysis of observational studies. *J Orthod* 2021;48:277-87.
 30. Lione R, Paoloni V, De Razza FC, Pavoni C, Cozza P. Analysis of maxillary first molar derotation with Invisalign clear aligners in permanent dentition. *Life (Basel)* 2022;12:1495.
 31. Cortona A, Rossini G, Parrini S, Deregibus A, Castroflorio T. Clear aligner orthodontic therapy of rotated mandibular round-shaped teeth: a finite element study. *Angle Orthod* 2020;90:247-54.
 32. Gaddam R, Freer E, Kerr B, Weir T. Reliability of torque expression by the Invisalign appliance: a retrospective study. *Australasian Orthodontic Journal* 2021;37:3-13.
 33. Zhang XJ, He L, Guo HM, Tian J, Bai YX, Li S. Integrated three-dimensional digital assessment of accuracy of anterior tooth movement using clear aligners. *Korean J Orthod* 2015;45:275-81.
 34. Tang Z, Chen W, Mei L, Abdulghani EA, Zhao Z, Li Y. Relative anchorage loss under reciprocal anchorage in mandibular premolar extraction cases treated with clear aligners. *Angle Orthod* 2023;93:375-81.
 35. Tao T, Liang H, Yan X, Fan Q, Jiang Q, Jian F, et al. Comparison of root parallelism in extraction cases treated with clear aligners vs. fixed appliances. *Appl Sci* 2022;12:11756.
 36. Ravera S, Castroflorio T, Garino F, Daher S, Cugliari G, Deregibus A. Maxillary molar distalization with aligners in adult patients: a multicenter retrospective study. *Prog Orthod* 2016;17:12.
 37. Garino F, Castroflorio T, Daher S, Ravera S, Rossini G, Cugliari G, et al. Effectiveness of composite attachments in controlling upper-molar movement with aligners. *J Clin Orthod* 2016;50:341-7.

38. Rossini G, Parrini S, Deregibus A, Castroflorio T. Controlling orthodontic tooth movement with clear aligners. *J Aligner Orthod* 2017;1:7-20.
39. Dai FF, Xu TM, Shu G. Comparison of achieved and predicted tooth movement of maxillary first molars and central incisors: first premolar extraction treatment with Invisalign. *Angle Orthod* 2019;89:679-87.
40. Santucci V, Rossouw PE, Michelogiannakis D, El-Baily T, Feng C. Assessment of posterior dentoalveolar expansion with Invisalign in adult patients. *Int J Environ Res Public Health* 2023;20:4318.
41. Zhou N, Guo J. Efficiency of upper arch expansion with the Invisalign system. *Angle Orthod* 2020;90:23-30.
42. Tien R, Patel V, Chen T, Lavrin I, Naoum S, Lee RJH, et al. The predictability of expansion with Invisalign: a retrospective cohort study. *Am J Orthod Dentofacial Orthop* 2023;163:47-53.
43. Houle JP, Piedade L, Todescan R Jr, Pinheiro FHSL. The predictability of transverse changes with Invisalign. *Angle Orthod* 2017;87:19-24.
44. Ma S, Wang Y. Clinical outcomes of arch expansion with Invisalign: a systematic review. *BMC Oral Health* 2023;23:587.
45. Kanpittaya P, Changsiripun C, Jaruprakorn T, Komolpis R, Chengprapakorn S, Laoamata V, et al. Clear aligner: effectiveness, limitations and considerations. *J Dent Assoc Thai* 2021;71:231-6.
46. Shah S. Clear aligners: an update. *EASJDOM* 2020;2:160-4.
47. Tai S. Clear aligner technique. Hanover Park IL: Quintessence Publishing Co; 2018.
48. Fontaine-Sylvestre C. Predictability of deep overbite correction using Invisalign [thesis]. Manitoba: University of Manitoba; 2019.
49. Xiang X, Wang C, Guan X, Wang L, Cang S. Treatment of an anterior open bite, bimaxillary protrusion and mesiocclusion by the extraction of premolars and the use of clear aligners. *Australasian Orthodontic Journal* 2023;39:72-85.
50. Meade MJ, Weir T. Treatment planning protocols with the Invisalign appliance: an exploratory survey. *Angle Orthod* 2023;93:501-6.