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The Efficacy of the Invisalign® Aligner Technique: An Overview

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ABSTRACT

Developed in 1997 by two students at Stanford University, the Invisalign® system revolutionized orthodontic treatment by integrating digital modeling with clear aligner technology as an alternative to traditional bracket-based mechanics. Since the introduction of SmartForce and SmartTrack material, the efficacy of the treatment has improved. There is still a shortage of high-quality evidence concerning the treatment modality. In order to make the treatment with the aligners more efficient, a correct management of the ClinCheck® software and a proper use of the biomechanics are necessary. The aligned force-driven system should be taken into account when developing the digital planning.

Keywords: Invisalign; Smart Force; Clin Check; Orthodontic Appliances; Orthodontic Treatment; Digital Planning

Introduction

Developed in 1997 by two students at Stanford University, the Invisalign® system revolutionized orthodontic treatment by integrating digital modeling with clear aligner technology as an alternative to traditional bracket-based mechanics. The use of aligners is gaining wide acceptance among adult and adolescent patients who prefer discreet and comfortable orthodontic solutions over conventional fixed appliances. Unlike brackets, removable devices minimize periodontal risks and enable patients to maintain optimal oral hygiene routines [1,2]. Clear aligners surpass fixed orthodontic appliances primarily in esthetics and comfort. Beyond these patient-centered advantages, the incorporation of ClinCheck® software facilitates precise biomechanical control and enhances the accuracy of dental movement planning. When protocols and precise staging are followed, dental movements are distributed across the different treatment phases through an algorithm-driven system of forces that enables the planned displacements. In the scientific literature, numerous systematic reviews have assessed the accuracy of Invisalign® movements; however, recent studies reflecting technological advancements must also be considered. Kravitz, et al. [3] reported a mean accuracy of 41% for anterior tooth movement with Invisalign®. A prospective study conducted in 2020, evaluating all types of tooth movements, demonstrated an improvement in overall accuracy to approximately 50%. Both investigations identified true incisor extrusion as the least predictable movement, followed by mandibular canine rotation, whereas lingual constriction was consistently observed as the most accurate [4]. The literature indicates that combining extrusion with lingual crown tipping (i.e., relative extrusion) enhances the predictability of tooth movement [5-9]. Given that the buccal and lingual crown surfaces provide the greatest contact area for force application, bucco-lingual movements are consequently the most reliable. Furthermore, the introduction of SmartForce® material, in conjunction with power ridges, has led to improved accuracy in achieving incisor buccal crown tipping [8]. Nevertheless, clinical challenges may occur in the movement of second molars, largely due to the limited aligner retention on the shorter terminal crowns and the reduced force exerted on the distal-most teeth within the appliance.

Regarding the rotation of rounded teeth, limitations remain despite the use of optimized attachments, particularly for rotations exceeding 5°. Reported accuracy was higher for mesial rotations (52%) compared with distal rotations (37%) [8], findings that are consistent with those of Simon, et al. [9-11]. Additionally, premolar

derotation has been further assessed by considering both the extent of movement achieved and the staging sequence implemented [12]. Findings indicate that predicted rotations exceeding 15°, as well as those staged at more than 1.5° per aligner, demonstrated significantly reduced accuracy [10]. Reported accuracy levels for specific tooth movements were particularly low: up to 28% for mesial rotation of the mandibular first molar, approximately 37% for distal rotation of the maxillary canine, and 35% for mandibular incisor intrusion, the latter result being consistent with the observations of Grunheid, et al. [12] The reduced precision of mandibular incisor intrusion may be attributed to insufficient posterior anchorage. Conversely, second molar intrusion showed relatively higher accuracy at 51%. Collectively, these outcomes support the conclusion that Invisalign® is more effective for bite closure than for bite opening [7,9,13].

With respect to transverse movements, ClinCheck® simulations tend to predict greater bodily expansion than is achieved clinically, where dental tipping is often observed at the end of treatment. This underscores the importance of careful planning, including overcorrection strategies and the use of auxiliary expansion methods, particularly in the posterior maxilla, to reduce the likelihood of midcourse corrections and refinements [4,14,15]. Duncan, et al. [15] further reported that maxillary crowding is predominantly addressed through interproximal reduction (IPR), while mandibular crowding is managed by IPR alone in 30% of cases, by IPR combined with incisor proclination in 40%, and by incisor proclination alone in 18%. Following Invisalign® treatment, 58% of patients demonstrated an increase in mandibular arch length [16].

A study by Hennessy, et al. [16] evaluating space recovery in mild crowding cases showed that fixed appliances produced 5.3±4.3° of mandibular incisor proclination, compared with 3.4±3.2° with Invisalign®, with no statistically significant difference between the two groups [16]. These findings highlight the clinical importance of employing buccal expansion (when indicated) and IPR to minimize unwanted lower incisor proclination during the treatment of crowded dentitions [15]. Finally, two independent investigations demonstrated that, over an 8-week period, there was no significant difference in orthodontic tooth movement (OTM) between patients who wore the same aligner for two weeks and those who switched to a duplicate aligner after one week. The reduced OTM observed during the second week was not attributable to material fatigue [5,6].

Conclusion

Although this review included a considerable number of studies, no clear clinical recommendations can be made, based on solid scientific evidence, apart from no extraction treatment of mild to moderate malocclusions in non-growing patients. There is still a shortage of high-quality evidence concerning the treatment modality.

The introduction of Smart Force® features and SmartTrack® material has enhanced the overall effectiveness of aligner therapy; however, inconsistencies remain in the way study outcomes are reported. From a clinical perspective, several considerations should be taken into account when planning treatment with clear aligners:

- **Transverse Correction**: Expansion of the maxillary arch occurs predominantly through coronal tipping rather than bodily movement, with predictability decreasing progressively in the posterior region.
- **Deep Bite Correction**: The predictability of deep bite resolution is limited, requiring meticulous planning in ClinCheck®. Correction is achieved primarily through proclination of the mandibular incisors (relative intrusion).
- **Open Bite Correction**: In contrast, the management of anterior open bite relies on a combination of incisor extrusion and lingual crown tipping (relative extrusion).
- **Crowding:** Optimal management of crowding necessitates the combined use of arch expansion and interproximal reduction (IPR) to minimize excessive incisor proclination.
- **Sagittal Correction**: Distalization of molars should generally not exceed 2–3 mm to maintain predictability.

End-of-Treatment Considerations: At the conclusion of treatment, the incisor position is frequently more occlusal than predicted, while premolar rotations and incisor torque corrections often remain partially unresolved.

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