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EVALUATING THE ACCURACY OF CLEAR ALIGNER THERAPY IN VARIOUS ORTHODONTIC TOOTH MOVEMENTS: A REVIEW STUDY

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ABSTRACT

Introduction: Clear aligner therapy (CAT) is one of the treatment methods that orthodontists use to treat different malocclusions. Initially, CAT was recommended for mild malocclusions, such as minor crowding, slight spacing, buccolingual tipping of teeth, and arch expansion. However, with the growing demand for and popularity of CAT and advancements in biomechanics, many orthodontists are now using CAT to treat more complex cases, including extraction cases, severe crowding, distalization, and surgical cases. The effectiveness of CAT is influenced by various factors, such as the complexity of the required tooth movements, the patient's level of compliance with wearing the aligners as prescribed, and the orthodontist's expertise. The quality of the aligner material and the precision of the treatment planning process can also impact the success of CAT. Despite the increasing popularity of CAT aligners provided by different companies, data in the literature remain limited regarding their predictability.

Aim: The aim of this article is to review the available data in the literature regarding the accuracy of CAT in achieving different tooth movements.

Conclusion: The predictability of tooth movement by CAT is multifactorial and depends on the type of tooth movement, the patient's compliance, and the orthodontist's experience. The recent advances in the biomechanics of CAT have improved the accuracy of its outcome. Buccolingual tipping is the most accurate movement when using CAT. Severe spaces (≥6 mm) have significantly lower predictability than mild spaces. CAT is more predictable in treating open bite by extrusion of the incisors and intrusion of the molars.

KEYWORDS: Clear aligner therapy, Accuracy, Predictability, Rotation, Tipping

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INTRODUCTION

A significant change in orthodontic treatment was brought about by Align Technology's 1997 introduction of Invisalign, which made clear aligner therapy (CAT) widely available. Because of its ease of use and invisible design, CAT quickly gained popularity as an alternative to conventional braces. This breakthrough led to the development of multiple other brands of CAT, increasing the options available to patients and orthodontists [1].

CAT is one of the treatment methods that orthodontists use to treat different malocclusions. Clear aligners apply gentle pressure to the teeth to gradually move them into the desired position. Some advantages of CAT over conventional braces are that CAT aligners are more comfortable to wear, have better esthetics, and are more hygienic [2]. Nevertheless, CAT has some drawbacks, including the need for patient compliance, unsuitability for all malocclusions, and a higher cost than traditional braces [3]. Initially, CAT was recommended for mild malocclusions, such as minor crowding, slight spacing, buccolingual tipping of teeth, and arch expansion. However, with the growing demand for and popularity of CAT and advancements in biomechanics, many orthodontists are now using CAT to treat more complex cases, including extraction cases, severe crowding, distalization, and surgical cases. Today, many companies offer CAT; however, regardless of the company or system used, we need more data regarding the predictability of CAT in treating various types of orthodontic malocclusions [4].

The effectiveness of CAT is influenced by various factors, such as the complexity of the required tooth movements, the patient's level of compliance with wearing the aligners as prescribed, and the orthodontist's expertise. The quality of the aligner material and the precision of the treatment planning process can also impact the success of CAT. The predictability of CAT varies from 55% to 72% [5]. Align Technology indicates that approximately 80% of the anticipated tooth movement should be evident in ClinCheck [6].

Despite the increasing popularity of CAT aligners provided by different companies, data in the literature remain limited regarding their predictability. The aim of this article is to review the available data in the literature regarding the accuracy of CAT in achieving different tooth movements.

MATERIAL AND METHODS

The terms "accuracy of clear aligners," "predictability of clear aligners," and "efficacy of clear aligners" were used as the keywords in our review. All the terms were searched in PubMed and Google Scholar. Original articles published in English language were included. A total of 11 articles were included in this review (Table 1).

Rotational and tipping movement

Various studies have reported on the reliability of CAT in rotational and tipping movement. A study by Lombardo et al. showed that the mandibular canine has the least accurate movement in rotation, at approximately 54%, whereas the mandibular molar has the most accurate movement, at approximately 85%. The study also identified mesiodistal tipping as the most predictable tooth movement, with a mean accuracy of 82.5%.

Vestibulolingual tipping and rotation achieved accuracies of 72.9% and 66.8%, respectively, for the prescribed movements. However, the predictability of different tooth movements varies significantly. For instance, the mesiodistal tipping of the upper molars and lower premolars, with accuracy rates of 93.4% and 96.7%, respectively, are the most predictable [7] (Table 2).

A study of 37 patients treated with CAT found that canines had lower accuracy for rotational movement compared to incisors on both the mandibular and maxillary arches [8]. Another study

TABLE (1) List of articles' titles and type of tooth the movements

Titles	Type of tooth movements
How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. (Kravitz et al.,2009)	Accuracy of buccolingual tipping, mesiodistal tipping, rotation, intrusion, extrusion, and expansion
Predictability of orthodontic movement with orthodontic aligners: a retrospective study (Lombardo et al., 2017)	Accuracy of buccolingual tipping, mesiodistal tipping, and rotation
How accurate is Invisalign in nonextraction cases? Are predicted tooth positions achieved? (Grünheid ey al., 2017)	Accuracy of tooth positions (mesial-distal, facial-lingual, and occlusal – gingival) Accuracy of tooth directions (torque, tip, and rotation)
The predictability of transverse changes with Invisalign. (Houle et al., 2017)	Accuracy of expansion
Accuracy of clear aligners: A retrospective study of patients who needed refinement. (Charalampakis et al., 2018)	Accuracy of horizontal tooth movement, vertical tooth movement, rotation, intrusion, and extrusion
The predictability of orthodontic tooth movements through clear aligner among first-premolar extraction patients: a multivariate analysis. (Linghuan et al., 2020)	Accuracy of space closure
Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign. (Haouili et al., 2020)	Accuracy of buccolingual tipping, mesiodistal tipping, rotation, intrusion, and extrusion
Predicted and actual outcome of anterior intrusion with Invisalign assessed with cone-beam computed tomography. (Al-Balaa et al., 2021)	Accuracy of intrusion
Predictability of crowding resolution in clear aligner treatment. (Fiori et al.,2022)	Accuracy of crowding resolution
Predictability of orthodontic space closure using Invisalign clear aligners: A retrospective study. (Barashi et al., 2024)	Accuracy of space closure
Predictability of tooth rotations in patients treated with clear aligners. (D'Antò et al., 2024)	Accuracy of rotation

involving 44 patients assessed the predictability of rotational movement and reported accuracy rates of 75% in the upper arch and 78% in the lower arch. That study also found that the second molars had the least accuracy in terms of rotational movement. In addition, it showed that in the lower arch, the incisors performed the best, whereas rounded teeth struggled with rotational movements. Conversely, in the upper arch, premolars were the most accurately moved teeth, whereas incisors were more prone to underperformance [9].

TABLE (2) Comparison of accuracy of buccolingual tipping, mesiodistal tipping, and the rotation movement in different teeth.

	Tooth	Upper incisors	Upper canines	Upper premolars	Upper molar	Lower incisors	lower canines	lower premolars	lower molars
Predictability of orthodontic movement with orthodontic aligners: a retrospective study (Lombardo et al., 2017)	Accuracy of buccolingual tipping	65%	54%	70%	52%	86%	66%	90%	78%
	Accuracy of mesiodistal tipping	77%	78%	78%	98%	88%	87%	97%	62%
	Accuracy of rotation	61%	62%	71%	78%	67%	54%	62%	85%
How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign (Kravitz et al., 2009)	Accuracy of buccolingual tipping	40.3%	44.6%	N/A	N/A	44.2%	43.7%	N/A	N/A
	Accuracy of mesiodistal tipping	38.6%	35.5%	N/A	N/A	39.6%	26.9%	N/A	N/A
	Accuracy of rotation	54.2%	32.2%	N/A	N/A	48.8%	29.1%	N/A	N/A

TABLE (3) Comparison of the accuracy of extrusion and intrusion in different teeth.

	Tooth	**Upper central incisors**	**Upper lateral incisors**	**Upper canines**	**Lower central incisors**	**Lower lateral incisors**	**Lower canines**
Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign (Haouili et al., 2020)	Intrusion	33.4%	44.6%	53.3%	33.9%	36.7%	51.3%
	Extrusion	56.4%	53.7%	42.2%	44.5%	47.1%	50.6%
How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign (Kravitz et al., 2009)	Intrusion	44.7%	32.5%	40%	46.6%	40%	39.5%
	Extrusion	18.3%	28.4%	49.9%	24.5%	28.4%	30.4%

Space closure and crowding:

One of the most common indications for CAT is slight spacing and crowding. Ren et al., in a study on 31 patients who had premolar extractions and were treated with CAT, found discrepancies between the actual tooth movements and the originally planned movements. These discrepancies included unwanted mesial tipping and intrusion of the molars, distal tipping of the canines, and both distal tipping and extrusion of the incisors. The authors suggested adding an overtreatment to the treatment plan to prevent these unwanted tooth movements [10]. Another study of 55 patients with spacing treated with CAT reported that 39 of the treated patients did not need refinements. The study also showed that severe spaces (≥6 mm) had significantly lower predictability compared to mild spaces (1–3 mm) [11].

For the correction of crowding, three main orthodontic strategies are available to resolve insufficient space in the arch without extractions: interproximal reduction, transverse arch expansion, and increasing the arch length by proclination of the incisors. The predictability of CAT in resolving crowding is approximately 87% in the maxillary arch and 81% in the mandibular arch, with interproximal reduction being the least accurate method for gaining space. By contrast, arch expansion showed better predictability in gaining space. Therefore, the need for additional aligners must always be considered to solve the crowding that may still be present to ensure a comprehensive and effective treatment plan [12].

Intrusion and extrusion:

One of the complicated tooth movements achieved by CAT to correct open bite and deep bite malocclusions is intrusion and extrusion. A prospective clinical study of 37 patients that evaluated the efficacy of tooth movement with CAT found that the least accurate movement was extrusion at 29.6% [7]. Haouili et al., in their prospective study of 38 patients treated with CAT, revealed discrepancies between the planned and achieved tooth positions regarding extrusion and intrusion movements. They reported that the accuracy of the extrusion of the incisor is generally more accurate than the intrusion. They demonstrated that extrusion of the upper incisor is significantly more accurate (56%) when compared with intrusion of the same tooth (33%). By contrast, the posterior teeth showed a better intrusive than extrusive result. The second lower molar obtained 37% extrusion accuracy, which was significantly less accurate than intrusion (51% for the same tooth). One important finding was that extrusion of the upper incisors was the most accurate, while extrusion of the upper and lower molars was the least accurate [4]. Other studies found intrusion movements challenging, especially in the anterior teeth [13,14]. A study 22 patients compared the predicted anterior teeth intrusion measurements with actual clinical intrusion measurements using cone beam computed tomography. Authored reported true anterior teeth intrusion was 51% [15].

Accuracy results indicating greater extrusion in the incisors and intrusion in the molars emphasize that CAT is more predictable in bite closure. Table 3 shows how recent advances in CAT biomechanics and attachment features have improved the accuracy outcomes of extrusion and intrusion movement.

CONCLUSION

The predictability of tooth movement by CAT is multifactorial and depends on the type of tooth movement, the patient's compliance, and the orthodontist's experience. The recent advances in the biomechanics of CAT have improved the accuracy of its outcome. To improve the predictability of the tooth movement with CAT, orthodontists play an essential role in the virtual plan by using their clinical knowledge, programming the movements at appropriate steps, and adding proper attachments and auxiliaries.

The conclusions drawn from this review are:

- Of all tooth movements, buccolingual tipping stands out as the most accurate when using CAT.
- Mandibular molars have higher accuracy in rotational movement than mandibular canines.
- Unwanted tooth movement occurs with premolar extraction space closure treatment.
- Severe spaces (≥6 mm) have significantly lower predictability than mild spaces.
- The predictability of space closure by CAT is approximately 70%.
- The resolution of crowding by CAT ranges from 81% to 87%, with interproximal reduction as the least accurate way to gain space.
- CAT is more predictable in treating open bite by extrusion of the incisors and intrusion of the molars.

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