Review Article

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Efficacy of clear aligner therapy over conventional fixed appliances in controlling orthodontic movement: A systematic review

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Abstract

OBJECTIVE: The purpose of the current systematic review was to answer the clinical research question "Is Clear Aligner Therapy (CAT) effective in controlling the orthodontic movement?" by bringing together the most up-to-date information about the available evidence for CAT.

METHODOLOGY: On January 1, 2023, a search was conducted in PubMed, ERIC, Embase, and CINHAL for any research papers published in the previous 10 years that provided an overview of the PICO questions. Both the titles and abstracts of the selected studies were evaluated independently by two different authors, and if there was any disagreement between the two review authors, a third reviewer was brought in to settle it.

RESULTS: Among included studies, three were retrospective non-randomized and two studies were prospective randomized clinical trials. Various authors reported better outcome for fixed orthodontic appliances than for clear aligner treatment (CAT) in relation to mandibular incisor proclination. The mean objective grading system score was better for braces (17) than for CAT (12) with no clinically significant difference, while staging had a significant impact on treatment efficacy.

CONCLUSION: The results of this study suggest that clear aligners may be an effective alternative to traditional braces, but more research is needed to confirm these findings and determine the optimal size of future prospective studies evaluating this treatment.

Keywords:

Clear aligner, clear correct, conventional fixed orthodontics, evidence-based dentistry, dentistry, Invisalign, invisible orthodontics, orthodontic therapy, systematic review

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Introduction

In recent years, there has been a rise in the number of a group of adults seeking orthodontic treatment,[1] and these patients have voiced a need for more esthetically pleasing and functional alternatives to traditional fixed appliances.[2] In 1946,[3] Kesling came up with the idea of using a series of thermoplastic tooth positioners to gradually move misaligned teeth to improved positions. This paved the way for the option to use clear orthodontic appliances, which were originally published in the same year. In 1997, a company based in Santa Clara, California, called Align Technology adapted recent technologies to publicize the benefits of clear aligner therapy (also known as CAT), as is known today. This made Kesling's idea a practicable orthodontic treatment option.[4] There have only been a scarcity of literature predicting the outcome of orthodontic treatment, despite the fact that clear aligner therapy has been touted as a comfortable, harmless, and esthetically pleasing orthodontic treatment for the adult patient.[4,5] The manufacturer

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of Invisalign claims that the product can successfully perform major tooth movements, including bicuspid derotation of up to 50 degrees and root movements of upper central incisors of up to 4 mm.[6] However, there is disagreement in the literature regarding the clinical applications of this system.[7] It is possible that this is due to the lack of knowledge regarding orthodontic treatment using removable thermoplastic appliances. Previous publications on Invisalign primarily focus on the technical aspects, various material studies, and various case reports).[4,8] Only two studies were included in a review of the effectiveness of Invisalign therapy published in 2005 by Lagravere and Flores-Mir (2005).[7] According to the authors, definitive statements cannot be made about the efficacy of the orthodontic procedure. Therefore, clinicians who wish to employ CAT on their patients must, therefore, rely on anecdotal evidence, expert opinion, and the limited published evidence.[7]

The purpose of the current systematic review was to answer the clinical research question "Is CAT effective in controlling the orthodontic movement?" by bringing together the most up-to-date information about the available evidence for CAT.

Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline was followed in order to conduct this review in the appropriate manner. Due to the nature of the investigation that was currently being conducted, permission from an institutional review board was not required.

Focused PICO question

PICO questions were developed in order to determine which studies would be most appropriate to answer: "Is CAT effective in controlling the orthodontic movement?" 1 Population: Patients indicated for orthodontic treatment; 2 Intervention: Clear aligner treatment; 3 Comparison: clear aligner therapy (CAT) effective in controlling the orthodontic movement vs conventional fixed appliances; 4 Outcome: orthodontic tooth movement.

Search strategy

On the first of January 2023, a search was conducted in the databases PubMed, ERIC, Embase, and CINHAL for any research papers published in the previous 10 years that outlined the PICO questions. Through the use of the search method, all of the relevant papers were discovered. In addition to that, every relevant article's reference list was also manually searched for information. In order to locate additional studies that were relevant to this one, a manual search was conducted on the hosting publishers (Wiley, ScienceDirect, and Springer), in addition to a search that was conducted independently on the renowned implant journals.

Eligibility criteria

In order for studies to be considered for inclusion in the systematic review, they must first demonstrate that they meet the inclusion criteria that are presented in the following paragraphs:

- Articles written in the English language.
- Original research conducted both prospectively and retrospectively subjects with permanent dentition teeth.
- Studies on the effectiveness of orthodontic treatment using clear aligners.
- Studies that adequately described the materials used and the methods that were applied.
- Studies that adequately analyzed the statistics.

The following were included in the criteria for exclusion:

- Studies on patients with genetic syndromes and sever facial deformities.
- Studies using surgical orthodontic techniques.
- Studies on patients: Case reports, reviews, abstracts, and other types of studies involving fewer than 10 patients and studies carried out on animals.

Selected studies

Two researchers, AA and EA, independently reviewed the research titles, abstracts, and keyword lists of the relevant publications in order to determine whether or not they met the criteria for eligibility. After that, the full texts of all potentially eligible papers were retrieved and meticulously examined in order to locate research that satisfies all the inclusion requirements. Following the resolution of any differences of opinion with the third reviewer, a list of the articles that will be considered for inclusion in this assessment was compiled (AA).

Gathering of data

Two different authors, each of whom was responsible for screening the titles and selecting the abstracts for full-text inclusion, evaluated the abstracts and titles of the chosen studies independently. By employing the mesh terms and adhering to the inclusion and exclusion criteria, we were able to retrieve all the pertinent full-text articles. A third reviewer was brought in to settle any disagreements that arose between the two review authors. The following pieces of information were extracted from the study's data: author, year of publication, study design, specifics of the intervention and comparison, outcomes, and statistical information.

Results

The initial search produced a total of 64 hit results (PubMed: 26, Scopus: 0, ERIC: 0 CINAHL: 38).

After getting rid of any duplicates and looking over the titles and abstracts, it was decided to conduct additional research on a total of ten full texts. Out of those ten, only five fulfilled the requirements to be included in this review, so the other five were eliminated. The PRISMA flowchart exhibiting the study selection process is presented in Figure 1.

Among included studies, three[9-11] were retrospective non-randomized and two studies[12,13] were prospective randomized clinical trials. The number of patients involved in the study was 225, with individual studies having sample sizes ranging from 10 to 75. The samples that were evaluated contained people ranging in age from 22.7 to 32.9 years old when they first began the aligner treatment. In the research, researchers utilized aligners made by Invisalign to do their work. Table 1, summarizing the comparison between clear aligner therapy and conventional fixed appliances.

Effects of interventions

Buccolingual tipping

Hennessy *et al*.[12] reported improved outcome for conventional orthodontic treatment than for clear aligner treatment (CAT) for mandibular incisor proclination (braces: 5.3 ± 4.3°; CAT: 3.4± 3.2°). However, the difference between two techniques was statistically non-significant (P >.05). Similarly, Lin *et al*.[13] also observed no statistical difference between braces and CAT for bucco-lingual inclination of incisors in their randomized controlled trial. Simon *et al*.[9] found no significant differences between the results obtained when the upper central incisor torque was supported by a horizontal ellipsoid attachment or by an altered aligner geometry (mean accuracy: 51.5 percent; SD = 0.2%). However, Caruso *et al*.[11] observed a statistically significant difference for 1^PP (the upper incisive inclination) (P < 0.01). Sfondrini *et al*.[10] in their retrospective study compared CAT with conventional and self-ligating brackets for upper incisal torque and noticed that 11^ANS-PNS (angle formed by the upper incisal axis with the palatal plane) and 11^OCL (angle determined by the axis of upper incisor and the occlusal plane) angles exhibited the greatest amount of numerical variation when using conventional brackets while aligners reported the lowest values overall. However, there was not a significant difference between the various approaches utilized for either perspective (P > 0.05). In addition, the I+ TVL (linear distance of the most advanced point of the vestibular surface of the upper incisor from the true vertical line) linear value variation did not exhibit any significant differences between the various groups that were examined (P > 0.05).

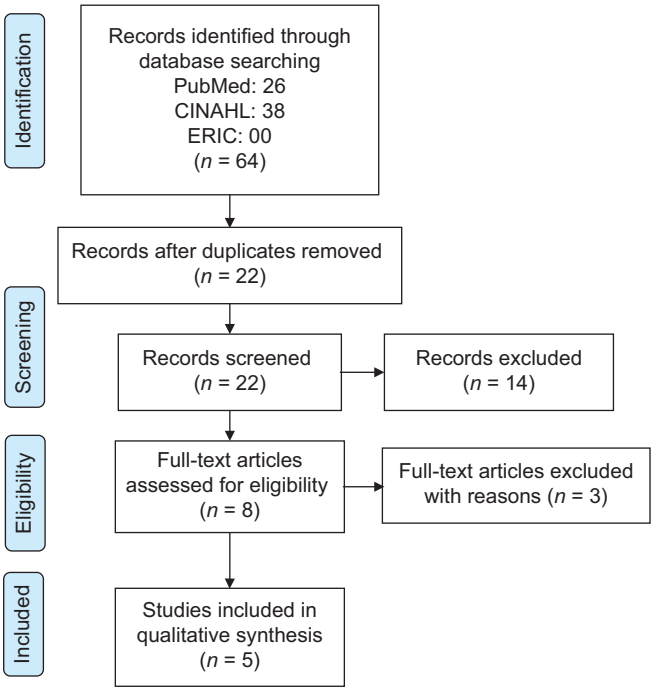

Figure 1: PRISMA flowchart for the study selection

Aligning

Lin *et al*.[13] in their randomized controlled trial reported an improvement of the objective grading score (OGS) for occlusal outcomes with fixed appliances and clear aligners. The mean OGS score was better for braces (17) than for CAT (12) with no clinically significant difference. On the other hand, there were no statistically significant differences between the groups when it came to the total OGS scores or the individual component either at the time of debonding or after 6 months of retention. During the post-treatment period, buccolingual inclinations and occlusal relations improved, while alignment and overjet significantly worsened in the group that had been using aligners. During the same time period, buccolingual inclinations became more prominent in the braces group, while alignment became more crooked.

Rotation

Simon *et al*.[9] reported that staging had a significant influence on treatment outcome: for rotation of premolars with a staging of <1.5°/aligner, the total efficacy was 41.8% (SD = 0.3%), whereas for premolar rotations with staging of >1.5°/aligner, the accuracy decreased to 23% (SD = 0.2%).

Vertical dentoskeletal dimension

Caruso *et al*.[11] reported no statistically significant difference (P = 0.421) between pre-treatment and after treatment with sequential distalization with orthodontic aligners for SN-GoGn and a mean variation of 0.1 ± 2.0 degrees was noted. However, in the linear position of the upper molars (6-PP, 7-PP) as well as in the molar class relationship parameter (MR), statistically significant differences were found with a P value of at least less than 0.01.

Table 1: Clear aligner therapy over conventional fixed appliances comparison summery

Author/Year	Study design	Patient no.	Mean Age (yrs)	M: F	Intervention	Comparison	Outcomes
Simon *et al*. (2014)[9]	Retrospective study	30	32.9	11:19	Superimposition of initial and final digital casts of Invisalign treatment	Treatment starting point and predicted movement made with Clin-Check	T2/Clin T2 ($P<.05$): Premolar derotation with attachments; Premolar derotation without attachments; Incisor torque with attachments; Incisor torque with PR
Hennessy *et al*. (2016)[12]	randomized, prospective clinical trial	fixed labial appliance: 22; Clear aligners: 22	26.4	17:27	Pre-treatment and post- treatment with Invisalign, measurement of mandibular incisor proclination	Outcomes of fixed labial appliance	Mandibular incisor proclination: Fixed appliances produced 5.3±4.3°; Clear aligners proclined the mandibular incisors by 3.4±3.2° ($P>0.05$).
Sfondrini *et al*. (2018)[10]	Retrospective study	Conventional brackets: 25; self-ligating appliance: 25; Clear aligners: 25	25.5	NR	Pre-treatment and post-treatment with Invisalign, position changes of upper central incisors using lateral cephalographs	Outcomes of Conventional brackets & self-ligating appliance	11^ANS-PNS: Conventional 6.11, Self-ligating 5.64, Aligner 5.13 ($P>0.05$); 11^OCL: Conventional 6.88, Self-ligating5.17, Aligner 4.60 ($P>0.05$); I+TVL: Conventional 1.56, Self-ligating 1.62; Aligner 1.47 ($P>0.05$)
Caruso *et al*. (2019)[11]	Retrospective study	10	22.7	2:8	Sequential distalization with Invisalign; pre-treatment and post-treatment cephalometric landmarks for occlusal vertical dimensions	Pre-treatment and post-treatment cephalometric landmarks	S-Go/N-Me: T0-0.62, T1-0.63; ($P=0.421$); 6-PP: T0-25, T1-23; ($P<0.0001$); 7-PP: T0-16, T1-13; ($P<0.0001$); 1^PP: T0-118.3,° T1-104.8°; ($P<0.006$); MR: T0-3.1, T1-1.2; ($P<0.0001$)
Lin *et al*. (2021)[13]	randomized controlled trial	fixed-appliance: 34; Clear aligners: 32	fixed-appliance: 25.9; Clear aligners: 26.7		Pre-treatment, post-treatment and 6-month retention OGS score after treatment with Invisalign	OGS scores of fixed appliances	OGS score: mean overall score: 17 (braces); 12 (Clear aligners); Alignment: 3.0 (braces); 2.0 (Clear aligners); Buccolingual inclination: 2.0 (braces); 2.0 (Clear aligners); Occlusal contacts: 2.0 (braces); 1.0 (Clear aligners); Overjet: 2.5 (braces); 1.0 (Clear aligners); Occlusal relations: 2.0 (braces); 2.0 (Clear aligners)

Discussion

According to the findings of the current systematic review, the aligners can be utilized in simple malocclusion with open bite which is difficult to treat.[14] When compared to other tooth movements, extrusion is the one that requires the least amount of accuracy to achieve with CAT,[4] and it can lead to larger deviation.[5] This inefficiency could be caused by the fact that it is difficult for the appliance to generate enough force to extrude teeth in a meaningful way. Upper molar distalization with orthodontic aligners, on the other hand, ensures a good control of the vertical dimension and is therefore a perfect remedy for hyperdivergent or open-bite treatment.[11] Also, previous research has shown that aligners are just as effective as fixed appliances in preventing vertical buccal occlusion, and this effect persists for years after treatment has ended.[15-18]

According to Elsevier 2018,[19] the amount of force necessary to cause tipping is comparable to the amount of force necessary to cause rotation of a tooth about its long axis. This could be because of spread of force to periodontal ligament than vertical strip.

As a result, it is difficult to put on a purely rotational force to the tooth without causing the tooth to tip in its socket. Using a backword-looking study design,[9] Simon *et al*. analyzed rotation of premolar >10° and found that the amount of movement per aligner and the use of attachments significantly affected the predictability of the treatment. Previous prospective studies[4,20] found that rotations were generally difficult to control and predictable. Orhan C. Tuncay (Editor)[21] also found that incisors rotated 60% of the way they were predicted to, while canines and premolars rotated only about 40% of the way (39%). So, it appears that CAT has a harder time rotating teeth with rounded crowns. In addition,[20] Kravitz *et al*. noted the positive rotation correction by interproximal reduction, and[16] Djeu *et al*. advocated the use of attachments to enhance the precision of this motion. Although there is lack of evidence on rotation control, it is always suggested to plan overcorrections, especially when rotations exceed 15°, to make use of attachments and to reduce staging to less than 1.5° aligners per aligner.

Because of the lack of control over tooth movement, it is widely assumed that clear aligners can simply tip crowns than root. According to[22] Drake *et al*. research, it is not possible to move teeth bodily while undergoing clear aligner treatment. The study analysis revealed a fundamental flaw in treatment planning while recording staging more than twice, which has doubled the rate per aligner that is currently prescribed for the treatment of patients. Consequently, if the maximum 2-week activation was reduced to 0.25 mm or less from 0.5 mm, a higher precision should be achieved. On the other hand,[9] Simon *et al*. discovered that when a distalization of the upper teeth of at least 1.5 mm was ordered, the patient's teeth move bodily with a high degree of accuracy. The authors found that when the motion was supported by tooth attachment, accuracy is increased. Furthermore, they emphasized the value of staging in identifying a treatment's potential for success. Difficulties in applying a pair of force with this kind of appliances may account for the conflicting results reported in the reviewed literature concerning the CAT tipping control. It appears that the root control can be enhanced by employing different aligner geometries and attachments.[9] For this reason, well-designed randomized controlled trials are required to determine whether or not CAT is actually effective in shifting crowns and roots along the arch.

The distalization of the upper molars and the sagittal vertical pattern were found to be adversely affected by a number of orthodontic appliances. These effects included a clockwise rotation of the mandibular arch and an increase in the anterior facial height, among others.[23-26] Based on these results, it seems that distalizing the upper molars is not advised for hyperdiverse individuals. Caruso *et al*.[11] 2019 found no divergence of subject which can be observed by variation of the SN-GoGn angle <1°, which they interpret to mean that clear aligners permit a good control of mandibular divergence in case distalizing molars. These findings are consistent with the unintended consequence that[27] Ravera *et al*. reported. Therefore, digitally planned orthodontic aligners appear to allow a good control of the vertical dimension and may recognize an effective alternative for upper molar distalization, especially in hyperdivergent or open-bite subjects, for distal molar movements of up to 2–3 mm.

One randomized controlled trial[13] found that CAT was as effective as fixed appliances at aligning the arches, with even better results for minimal crowding. The rate of relapse, which appears to be higher in the case of permanently installed devices, warrants special consideration.[17] It has been assumed that teeth that were moved using aligners did not go through the typical stages of movement[17] that were described by Krishnan and Davidovitch, 2006.[28] This hypothesis is based on the fact that aligners exert intermittent forces on the teeth. Orthodontic tooth movement can be achieved with less cellular damage in the periodontium using intermittent forces, whereas periodontium intermittently perceives orthodontic forces.[29,30] This suggests that the orthodontist, rather than the method, is the driving force behind these outcomes.

Conclusion

In conclusion, CAT is a reliable method for straightening the teeth of patients who are looking for esthetic treatment. Even with rounded teeth, CAT is able to effectively manage rotations. When a distalization of 1.5 mm is prescribed for the upper molars, CAT is effective in preventing abnormal molar movement. The use of aligners is only one component of CAT. Auxiliary devices (modified aligner geometries, attachments, and interarch elastics) are used to increase the accuracy of predicted orthodontic movement. The results of this study suggest that clear aligners may be an effective alternative to traditional braces, but we believe that difficult cases are still not suitable for CAT. Therefore, more research is needed to confirm these findings and determine the optimal size of future prospective studies evaluating this treatment.

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Conflicts of interest

There are no conflicts of interest.

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