

Treatment Outcome and Efficiency of Aligners Compared with Conventional Fixed Appliances: A Systematic Review

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Abstract

Background: Over the years, aligner therapy has undergone a great evolution. The use of aligners is now an alternative to braces for aesthetic reasons. Their effectiveness and impact have yet to be evaluated. **Objective:** The objective of this study was to compare the effectiveness of dental movements with aligners versus the use of conventional appliances, as well as the effectiveness and impact on periodontal health and root resorption. **Materials and Methods:** A systematic search of PubMed, Ebsco Host and Scopus was performed using a well-designed formula. Articles published in the last 10 years in English and French were included after filtering the titles, abstracts then full texts. **Results:** Twenty-six records were deemed suitable for the objectives of our systematic review. All records focused on the comparison of treatment with aligners and fixed appliances. The difference in treatment and time efficiency was assessed in 17 papers, 6 papers evaluated the impact of orthodontic appliances on periodontal health, and the remaining 3 records focused on the occurrence of root resorption. **Conclusion:** Clear aligners produce clinically acceptable outcomes that could be comparable to fixed appliance therapy. Aligners facilitate oral hygiene practices which results in better periodontal health. However, it appears that Invisalign may not be as effective as fixed appliances in achieving certain tooth movements like vertical, radicular and rotational movements.

Keywords: Aligner, Invisalign, Traditional Orthodontic Treatment.

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BACKGROUND

In 1999, Invisalign® was presented to the American Congress of Orthodontists by Align Technology [1]. Since then, Invisalign® therapy has undergone significant expansion worldwide and has become increasingly popular. Their major strengths are being esthetic, offering greater comfort to the patient and enhanced oral and periodontal hygiene. The technical improvement extends their indications from simple cases of crowding to more complex malocclusion.

MATERIALS AND METHODS

Objective of the Study

The purpose of this review was to identify the outcome of aligner's treatment, to compare the treatment efficiency of orthodontic aligners and traditional fixed appliances in addition to the assessment of the treatment effectiveness and stability.

Focused Question

This study looked at the following questions:

1. Do aligners have comparable treatment efficacy and results to conventional braces?
2. How differently do aligners and fixed devices effect periodontal health?

Identification of the research elements

The research elements were developed according to the PICOS schema standing for population, intervention, comparator, outcome, and study design. In the current systematic review, the constituents were defined as follows:

- **Population:** Adult patients with dental malocclusion.
- **Intervention:** Orthodontic treatment with removable aligners.
- **Comparison:** Orthodontic treatment with fixed appliances.
- **Outcomes:** The primary outcome was treatment effectiveness: the outcome assessment of the treatment included arch width, occlusal contacts, alignment, derotation, inclination of teeth and relapse; the secondary outcome was treatment duration, impact on periodontal health and orthodontically induced external root resorption.
- **Study Design:** Systematic review/ cohort study/ case series /meta-analysis / randomized controlled study /retrospective study /prospective study.

Search Strategies

The literature search of the articles was undertaken on the MEDLINE® database, using PubMed, Scopus and EBSCO databases until July 2022. The terms of the search were identified based on a scan of the keywords in the relevant articles. The search process included the following keywords: “aligner”, “clear”, “removable”, “Invisalign”, “fixed appliances”, “traditional orthodontic treatment”, “conventional orthodontic treatment”, “braces” and “brackets”. The search restrictions included publication date; articles published in the previous 10 years, language; leaving only English and French written papers, as well as full text and references availability.

Using the Boolean operators AND/OR the following Boolean formulas were worded:

- **Boolean formula #1:** ((Orthodont* OR clear OR removable) AND aligner*) OR (Invisalign@)
- **Boolean formula #2:** Conventional orthodontic treatment OR traditional orthodontic treatment OR brace* OR bracket* OR fixed appliance*
- **Boolean formula #3:** #1 AND #2

Articles Selection Process

Eligibility Criteria

The inclusion and exclusion criteria for admittance are presented in Table 1.

Table 1: Inclusion and exclusion criteria of our study

Inclusion criteria	Exclusion criteria
Population: Patients with permanent dentition who have problems with malocclusion.	Population: Patients with temporary or mixed dentition.
Document Type: Systematic reviews, meta-analysis, randomized controlled trials, case control studies, cohort studies, case series including more than 10 cases, prospective and retrospective studies	Document Type: Reviews, case reports, in vitro studies, books, conferences, author opinion, animal studies.
Comparison: The comparison group treated with fixed appliances.	Articles that are out of topic documents that outline, orthodontic treatment using activators, functional appliances and retainers. Papers with limited number of patients. Studies with fewer than 10 patients.
Outcome: Studies providing results of orthodontic treatment.	
Intervention: Orthodontic treatment using transparent appliances and fixed appliances	

Study Selection

Zotero software has been used to load all search results, remove duplicates and manage citations and bibliographies. The study selection process was carried out in two steps independently: initial screening of titles and abstracts of all studies according to pre-determined inclusion criteria then full text assessment. Any discrepancies between the review authors would be handled by discussion with a third researcher.

Data Extraction

The relevant data presented in the articles featured in this study were extracted according to a customized data collection form and then results were confronted, discussed and revised by the working group. Data collection and synthesis were presented in table 2.

Assessment of the Risk of Bias in Included Studies

Using the “JBI’s critical appraisal tools” [2], members of the research group independently assessed the risk of bias in included studies after article selection. After answering the questions listed in the JBI critical appraisal tool checklists, the percentage of detailed information is calculated which allows us to rank the risk of bias:

- >70% the study is considered to have a low risk of bias.
- 50%-70% the study has a moderate risk of bias.
- <50% the study has a high risk of bias.

The critical evaluation procedure and evaluation scores are listed in table 3.

Level of Evidence and Quality Assessment

According to the Oxford center of evidence-based medicine [3], levels of evidence were assigned to the included articles.

RESULTS

Study Selection

The search resulted in a total of 536 documents. After removing duplicates, 480 items were retained.

A pre-selection was carried out by examining the titles, which allowed us to exclude 380 articles. The remaining 100 papers were reviewed by abstract and resulted in the exclusion of 52 papers, leaving 48 valid papers by title and abstract that passed to the full text screening. The process came to include of 26 articles. The global selection process is illustrated in the PRISMA flow diagram (figure 1).

Study Characteristics

The research resulted: 1 randomized controlled study, 6 systematic reviews, 3 systematic reviews with meta-analysis, 2 meta-analysis, 7 retrospective studies, 2 prospective studies (1 nonrandomized), 3 cohort studies and 2 case control studies.

Studies were collected with a publication date limited to 10 years, from 2012 to 2022. The peak was reached in 2019, with 6 published articles identified that year. The curve is ascending showing the growing interest of researchers and dentists in this topic.

There were 15 individual papers among the 26 articles that were included, with a total of 1207 patients. In total, the sample size varied from 30 [4] to 300 [5]. Participants ranged in age from 19 to 62 years. They were adults and had full permanent dentition.

The orthodontic appliances used were clear aligners, mainly Invisalign®. In each study, the control group was treated with fixed orthodontic appliances.

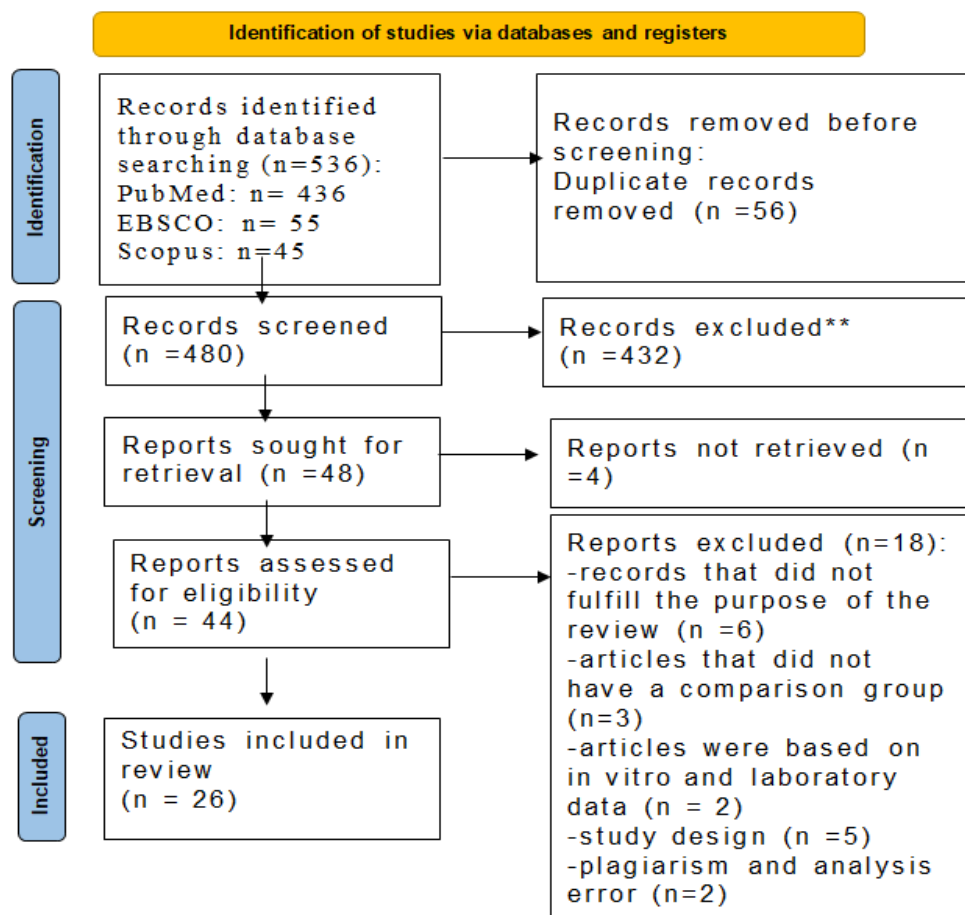


Fig. 1: PRISMA 2020 flow diagram

Table 2: Epidemiological and clinical data

Study ID	Title /Study design	Population	Intervention	Comparison	Outcomes	Conclusion
Hennessy 2016 [6]	A randomized clinical trial comparing mandibular incisor proclination produced by fixed labial appliances and clearaligners (RCT)	Mean age 26.4 ± 7.7 44 Participants	Invisalign® Treatment duration: 10.2 Months. Mean number of aligners used for each patient:18 IPR: 1.96± 1.3 mm	Self-ligating, preadjusted edgewise brackets Treatment duration: 11.3 months IPR: 1.56 ±1.2	Invisalign® produced a mean proclination of 3.46±3.2° and fixed appliances proclined the mandibular labial segment by 5.36±4.3° but the difference was statistically insignificant (P <.05).	There was no difference comparing mandibular incisor proclination produced by Invisalign® and fixed I appliances treatment in mild crowding cases.
Sfondrini 2018 [7]	Buccolingual Inclination Control of Upper Central Incisors of Aligners: A Comparison with Conventional and Self-Ligating Brackets (A retrospective controlled clinical trial)	Mean age 25.5 ± 6.5 50 patients	Invisalign®	Conventional brackets self-ligating appliances	11^SnaSnP and 11^Ocl angles showed the highest numeric variation with Conventional brackets. Lowest values were reported with aligners. Differences among various techniques were not significant for both angles. I+ TVL linear value did not show significant differences among the different groups tested	Based on these results, all the three different systems showed good clinical reliability in the upper incisor torque control.
Garnett 2019 [8]	Cephalometric comparison of adult anterior open bite treatment using clear aligners and fixed appliances A retrospective study (controlled clinical trial)	Mean age 34.5±9.0 53 patients	Invisalign® G4 exerts intrusive forces on the posterior teeth and extrusive forces on the anterior teeth by using optimized attachments. Number of patients: 36 Age: 35.3±7 Treatment times 1.6±0.6 years	Conventional brackets and self-ligating appliances TADs utilized in 4 cases for molar intrusion. In 1 case, a lower bite block was utilized. 7 cases were with PM extraction. Number of patients: 17 Age: 32.8±11.9 years .Treatment times: 1.6±0.7 years	Overbite change at the end of treatment was 2.3 mm for the clear aligner group and 1.8 mm for the fixed appliance group. Extrusion of the upper and lower incisors slightly greater in aligners group	The magnitude of anterior open bite correction obtained using clear aligners and fixed appliances did not demonstrate a statistically significant difference in adult hyperdivergent patients.

Grünheid 2016(11)	Kankam 2019 [10]	Buschang [5] 2014	RASK 2021(9)
Effect of clear aligner therapy on the buccolingual inclination of the mandibular canines and the intercanine distance (A retrospective cohort study)	Comparing Outcomes in Orthognathic Surgery Using Clear Aligners Versus Conventional Fixed Appliances (A cohort study)	Comparative time efficiency of aligner therapy and conventional edgewise braces A retrospective and prospective study (Clinical controlled trial)	Cephalometric evaluation of changes in vertical dimension and molar position in adult non-extraction treatment with clear aligners and traditional fixed appliances Observational retrospective longitudinal study (Clinical controlled trial)
Mean age: not specified 60 patients	Mean age 19.99 years 33 patients	Mean age : Not specified 300 Patients	Mean age Not Specified 66 Participants
Invisalign® 30 patients 8 male and 22 female Mean age: 25.0±11.8 IPR= 0.38±0.48 mm Treatment time: 13.4±6.8 months	Invisalign® Number: 13 patients	Clear aligner therapy 150 patients age: 29.0 years	Invisalign® Number of patients: 44 27 females and 17 males Age:41.26±14.59 years Treatment period: 2 years
Edgewise appliances ; 30 patients 8 male and 22 female Mean age:26.3±13.5 IPR= 0.14±0.40 mm Treatment time: 20.2±5.3 Months	Fixed appliances Number: 20 patients	Arch wire sequences: 0.016-inch NiTi, 0.016-inch ss, 0.022-inch ss 150 patients age: 13.0 years	Edgewise brackets. Number: 22 patients. 16 females and 6 males Age: 32.01±11.81 years Treatment period: 2 years
Canine buccolingual inclination was higher with Invisalign®. This change was not statistically significant. Intercanine distance increased in Invisalign® group but remained unchanged in edgewise group.	no significant difference in any of the parameters assessed	Duration of aligner therapy was shorter. Patients had 67% fewer appointments, spent 50% less time in the chair and had a significantly Lower number of emergency visits than fixed appliances patients.	Traditional fixed appliances showed slightly larger lower molar Extrusion compared to clear aligners which can be a side effect of elastics
Orthodontic treatment with clear aligners tends to increase the mandibular intercanine distance. Treatment with fixed appliances leads to more upright mandibular canines.	Perioperative outcomes and postoperative edema are not significantly affected when clear- aligner therapy is used as an alternative to conventional fixed appliances. the use of Invisalign® should not be considered a contraindication for surgery.	treatment modality using aligners have been shown to be more efficient than conventional brackets in terms of treatment duration, total chair time and total doctor time.	Anterior overbite decreased more in the traditional fixed appliance therapy than clear aligner therapy. Aligners did not provide a better vertical dimension control than traditional fixed appliances.

<p>Lanteri 2018 [13]</p> <p>The efficacy of orthodontic treatments for anterior crowding with Invisalign® compared with fixed appliances using the Peer Assessment Rating Index A retrospective study</p> <p>Mean age Not specified</p> <p>200 patients</p> <p>Invisalign® 100 patients 30 males and 70 females Mean age: 28±10 years Treatment duration: 14 Months</p> <p>Straight-wire Edgewise appliances Number of patients:100 30 males and 70 females Mean age: 25±10 years Treatment duration:19 (±4) months</p> <p>The only statistical difference was the shorter duration of Invisalign® treatment.</p> <p>Considering the reduction in PAR Index score, more than 90% of the patients treated with Invisalign® achieved satisfactory results.</p>	<p>Iglesias-Linares 2017 [4]</p> <p>Orthodontically induced external apical root resorption in patients treated with fixed appliances vs removable aligners (A case control study)</p> <p>Mean age 27.69±13.6 years</p> <p>30 patients</p> <p>Invisalign®</p> <p>Fixed appliances (Not specified)</p> <p>there was no statistically significant difference between the two groups</p> <p>The clinical study suggests that the predisposition to OI/EARR with Invisalign® is similar to that of using fixed appliances</p>	<p>Gu 2017 [1]</p> <p>Evaluation of Invisalign® treatment effectiveness and efficiency compared with conventional fixed appliances using the Peer Assessment Rating index (A retrospective case)</p> <p>Mean age 24±9 Years</p> <p>96 patients (Female 62, male:34)</p> <p>Invisalign® Number: 48 patients 32 Female, 16 male Mean age: 26.0±9.7 years Treatment duration: 13.35 months.</p> <p>Fixed appliances Number: 48 patients (Female 30, male:18) Mean age: 22.1±7.9 years Treatment duration:19.08 months</p> <p>Data indicated that fixed appliances are significantly more effective to reduce weighted PAR scores than invisalign®</p> <p>Fixed appliances improved malocclusion more effectively than Invisalign®. Treatment with Invisalign® was finished on average 30% (5.7 months) faster than treatment with fixed appliances</p>	<p>Henick 2021 [12]</p> <p>Effects of Invisalign® (G5) with virtual bite ramps for skeletal deep overbite malocclusion correction in adults A retrospective study (Controlled clinical trial)</p> <p>Mean age : Not specified</p> <p>48 Participants</p> <p>24 patients 15 women, 9 men Age:37.2±17.7 years Mean number of maxillary trays:33.17 Mean number of mandibular trays:31.17</p> <p>Standard edgewise fixed appliances Number: 24 patients women=16, men=8 Mean age: 27.1±10.4 years</p> <p>The following measurements were found to be statistically significant: ANS–Menton, overbite, ANB, upper lip to E-plane, lower lip to E-plane, L1–MP, U6–PP, ODI, IMPA, UI–SN, and nasolabial angle.</p> <p>Although fixed appliances treatment has more apparent skeletal change for deep bite adult patients when compared with G5 Invisalign®, both systems appear effective in Opening deep bites at the dentoalveolar and skeletal levels.</p>
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<p>Kumar 2021 [17]</p>	<p>Comparison of Apical Root Resorption in Patients Treated with Fixed Orthodontic Appliance and Clear Aligners: A Cone-beam Computed Tomography Study (Cohort retrospective study)</p>	<p>Mean age 23.71 ± 6.3 years</p>	<p>Clear aligners Mean age: 21.62 ± 3.58 years Number: 55 patients 21 males and 34 females</p>	<p>Fixed appliances Mean age: 23.71 ± 6.37 years Number: 55 patients 23 males and 32 females</p>	<p>The mean value of ARR in the fixed orthodontic appliances group was 1.51 ± 1.34 mm, whereas in the clear aligners group was 1.12 ± 1.34 mm.</p>	<p>the amount of resorption at the root apex is less in patients who are treated using clear aligners as compared with those treated with conventional fixed orthodontics appliances</p>
<p>Karkhanechi 2013 [16]</p>	<p>Periodontal status of adult patients treated with fixed buccal appliances and removable aligners over one year of active orthodontic therapy (Nonrandomized prospective study (Controlled clinical trial))</p>	<p>42 patients</p>	<p>Invisalign® 20 patients (12 females 8 males) Age: 28±6.86 years</p>	<p>Fixed appliances 22 patients 16 females, 6 males Age: 34±7.18 years</p>	<p>At 6 weeks plaque index, gingival index, bleeding on probing showed no difference between the two appliances. At 6- and 12-months scores for fixed group were higher than aligner group.</p>	<p>The use of removable aligners facilitates oral hygiene. Treatment with removable aligners was associated with improved periodontal status.</p>
<p>Madariaga 2020 [15]</p>	<p>Impact of Fixed Orthodontic Appliance and Clear Aligners on the Periodontal Health: A Prospective Clinical Study</p>	<p>Mean age 27.6±12.6 Years</p>	<p>40 patients</p>	<p>Clear aligners number: 20 patients Age: 34.7±12.5 years</p>	<p>Statistically significant decrease in both groups was found for plaque index, bleeding on probing, probing depth. Results suggested that the type of appliance did not have any effects on the improvement of periodontal variables.</p>	<p>no evidence of difference was observed in the periodontal health of patients undergoing fixed orthodontic therapy and clear aligner therapy, when a dental hygienist provided regular check-ups and adequate oral hygiene</p>
<p>Papageorgiou 2020 [14]</p>	<p>Treatment outcome with orthodontic aligners and fixed appliances: a systematic review with meta-analyses</p>	<p>Mean age 52.97±9.1</p>	<p>35 patients 14 males /21 females</p>	<p>Clear aligner (not specified) Treatment duration: 6.03±2.34 months</p>	<p>PAR index found no significant differences between aligners and conventional brackets ABO-OGS components showed that treatment with clear aligners is associated with worse treatment outcome compared to fixed appliances</p>	<p>Treatment with aligners is linked to worse treatment results compared to braces</p>
<p></p>	<p></p>	<p></p>	<p></p>	<p>Fixed appliances Treatment duration: 4.16±1.71 months brackets were bonded from canine to canine in the maxilla or the mandible.</p>	<p></p>	<p></p>

Table 3: Risk of bias in included studies

Article	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Assessment
Methodological appraisal of randomized controlled trial														
[6]	Y	Y	Y	X	X	X	Y	Y	U	Y	Y	Y	Y	69.2% Moderate
Methodological appraisal of systematic reviews														
[18]	Y	Y	Y	Y	Y	U	Y	Y	Y	U	Y			81.8% Low
[19]	X	Y	Y	Y	Y	U	U	Y	NA	Y	X			60% Moderate
[20]	X	Y	Y	Y	Y	U	Y	Y	X	Y	Y			72.7% Low
[21]	X	Y	Y	Y	Y	Y	Y	Y	X	Y	U			72.7% Low
[22]	X	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y			90% Low
[23]	X	Y	Y	Y	Y	U	U	Y	NA	Y	Y			70% Low
[24]	X	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			90.9% Low
[25]	X	Y	Y	Y	U	Y	Y	Y	NA	Y	U			70% Low
[26]	X	Y	Y	Y	Y	Y	Y	Y	X	X	Y			72.7% Low
[27]	X	Y	Y	Y	Y	Y	Y	Y	X	Y	Y			81.8% Low
[1]	Y	Y	Y	Y	Y	Y	Y	Y	X	Y	Y			90.9% Low
Methodological appraisal of cohort studies														
[11]	Y	Y	Y	U	U	Y	Y	Y	Y	X	Y			72.7% Low
[10]	Y	Y	Y	U	U	Y	Y	Y	Y	X	Y			72.7% Low
[17]	Y	U	U	X	X	Y	Y	Y	Y	Y	Y			63.6% Moderate
Methodological appraisal of case control studies														
[4]	Y	Y	Y	Y	Y	X	X	Y	Y	Y				80% Low
[16]	Y	Y	Y	Y	U	Y	Y	Y	U	Y				80% Low
Methodological appraisal of quasi experimental studies														
[12]	Y	Y	Y	Y	Y	Y	Y	Y	Y					100% Low
[9]	Y	Y	Y	Y	X	U	Y	Y	Y					77.7% Low
[8]	Y	Y	X	Y	Y	Y	Y	Y	Y					88.8% Low
[5]	Y	Y	Y	Y	X	U	Y	Y	Y					77.7% Low
[14]	Y	Y	Y	Y	Y	Y	Y	Y	Y					100% Low
[28]	Y	Y	Y	Y	X	Y	Y	Y	Y					88.8% Low
[7]	Y	X	Y	Y	X	Y	Y	Y	Y					77.7% Low
[13]	Y	X	Y	Y	Y	Y	Y	Y	Y					88.8% Low
[15]	Y	Y	Y	Y	X	Y	Y	Y	Y					88.8% Low

Y= Yes; X= No; U= Unclear; NA= Not Applicable

Certainty Assessment

The level of scientific evidence is assigned to each of the included studies according to the criteria outlined by the Oxford Center for Evidence-based Medicine and presented in the table 4. Most articles

were of grade B recommendation (96.15%); level of evidence 2a was assigned to 42.3% of the studies, 46.15% were of level 2b and 7.7% of the records were of level of evidence 3b. Only one study of grade A (3.9%) had a level of evidence of 1b.

Table 4: level of scientific evidence

Reference	Level of evidence	Grade of recommendation
[12]	2b	B
[18]	2a	B
[6]	1b	A
[19]	2a	B
[20]	2a	B
[21]	2a	B
[9]	2b	B
[8]	2b	B
[5]	2b	B
[22]	2a	B
[14]	2b	B
[11]	2b	B
[10]	2b	B
[17]	2b	B
[23]	2a	B

Reference	Level of evidence	Grade of recommendation
[28]	2b	B
[24]	2a	B
[4]	3b	B
[7]	2b	B
[16]	3b	B
[25]	2a	B
[26]	2a	B
[13]	2b	B
[27]	2a	B
[15]	2b	B
[1]	2a	B

DISCUSSION

Comparison of the Effectiveness: Treatment Outcomes

Adequate occlusal contacts are difficult to achieve with aligners. A systematic review by Python *et al.*, [19]. Clearly explained the difference in the OGS score in the occlusal contact. Tooth intrusion or extrusion was possible with fixed appliances within the 0.5-mm limits. Those vertical movements are hardly attainable with aligners. The trays cover the occlusal surfaces of teeth and prevent the occlusion from setting.

Ke *et al.*, [25] support these findings and report that there was a discordant outcome in terms of occlusal rapport and overjet. Extraction cases found no statistically significant difference between the two groups, but non-extraction cases had statistically lower scores for clear aligners. Authors claim that this was possible because the extraction space was used to fix the overjet.

The results obtained from these studies confirm that rotational and vertical movements are the least predictable types of movement. Rotations of canines and premolars were the most difficult to achieve. It is recommended that for rotation, using IPR, auxiliary attachments and not exceeding 1.5° of rotation per aligner. Supplementary techniques should be integrated when corrections above 15° are needed [22].

Many studies listed in this systematic review showed that Invisalign® has succeeded in aligning and leveling. Nevertheless, the movement of the tooth is achieved through the movement of the crown. Root movement is much more difficult to control with aligners.

Invisalign® expands dentoalveolar width in non-extraction cases treatment with mild and several crowding. However, modification of intercanine and intermolar widths is significantly more important with self-legating brackets. Grünheid *et al.*, [11] assessed the intercanine distance where they found no change during treatment with traditional devices but increased slightly with the aligners. This finding may be attributed to buccal tipping of canines with aligners. In contrast, the

fixed appliance uprighted more mandibular canines which resulted mainly from the control of root movement.

Aligners seem to be effective in correcting more severe malocclusions notably deep bite and open bite.

Open Bite Correction

Garnett *et al.*, in 2019 [8] conducted a cephalometric based comparison of open bite treatment with clear aligners and fixed appliances. A magnitude of overbite correction was achieved by both removable and fixed appliances with no significant difference between the two appliances. Open bite correction was obtained by the retroclination of the upper and lower incisors and no extrusion of the posterior teeth. Clear aligners had moderately higher lower incisor extrusion which resulted in relatively better correction of the overbite. Comparing aligners and fixed appliances in vertical control, Rask *et al.*, [9] showed also that both Invisalign® and fixed braces did not induce maxillary molar extrusion. With fixed appliances, there is a higher extrusion of mandibular molar under the effect of elastics. Clear aligners only induce lower molar extrusion when they are planned in the clincheck. With both devices, fixed and removable, the results showed no differences in the treatment of open bite.

Deepbite Correction

Through the evaluation of cephalometric measurements Henick *et al.*, [12] found that G5 aligners could significantly reduce skeletal deep bite. These findings may result from the efficacy of the bite ramps in disoccluding the molars producing more extrusion and mandibular backward. Incisor intrusion may have been greater with Invisalign® compared to fixed braces. Overbite decreased significantly with both the traditional braces and Invisalign®, but there was a greater decrease with the fixed braces.

It was observed that for patients undergoing the same retention protocol, Invisalign® treatment had more relapses than fixed appliances did. The two-week interval between aligners in the Invisalign® system is presumably too short, compared to brackets that are

normally fitted every 4-6 weeks, resulting in poor bone formation and more relapse [23, 25]. Another possible reason may be the shortcomings in accomplishing bodily movement and stable occlusal contacts [27]. Authors recommend overcorrection with Invisalign® because of the lack of total movement and poor root control, which leads to the tooth tipping uncontrollably and thus may result in relapse.

Comparison of Time Efficiency

We evaluated the effectiveness between Invisalign® and fixed devices based on the duration of the treatment. Bushang *et al.*, [5] conducted a trial showing that Invisalign® treatment duration was 67% shorter than conventional treatment in patients having mild-to moderate Class I malocclusions most likely because it does not require a finishing or detailing phase. According to Djeu *et al.*, [29], the treatment time for the fixed devices group (1.7 year) was significantly much longer than aligner group (1.4year). Shorter or similar treatment time for mild to moderate non-extraction malocclusions with Invisalign® compared to fixed brackets, but the time was longer for extraction cases. The studies were controversial, and some stated that there were no significant differences.

Impact of Orthodontic Treatment on Periodontal Health:

A meta-analysis carried by Lu *et al.*, [24] indicated that Invisalign® aligners are more conducive to the maintenance of periodontal health. These findings are in accordance with a clinical trial conducted by Karkhanechi *et al.*, [16] showing that there was less plaque accumulated using aligners after 6 and 12 months compared to conventional braces. The reasons could be the ability to take off the trays while brushing teeth, which allows to properly clean the device and the teeth and the use dental floss. Orthodontic treatment is sometimes considered to be a predisposing factor for periodontal disease because fixed appliances may prevent complete oral hygiene procedures and cause bacterial aggregation. These findings seem to contradict to the result of Madariaga *et al.*, [15] showed no difference between clear aligners therapy and fixed orthodontic treatment, when the treatment was assisted by a dental hygienist for 3 months. The study showed that the device used for orthodontic treatment doesn't have an impact on periodontal health if proper hygiene is maintained. Despite the common use of the aligners, there is still no robust evidence about the influence on periodontal indexes. Further RCTs in this field should be conducted.

A case control study by Iglesias-Linares *et al.*, [4] and a systematic review undertaken by Fang *et al.*, [26] agreed that the use of clear aligners cannot help to minimize the incidence of root resorption. Aligners and multibracket devices use different type of force, which is intermittent and continuous, respectively. Aligners by using intermittent forces cause less root resorption. It

has been also reported that although differences in the amount and level of force might be expected to contribute to differences in orthodontically induced root resorption expression. Yet recent fixed appliance protocols generally imply the sequential use of low intensity forces in every step, possibly explaining why the tendency to root resorption with conventional devices is similar to that with invisible aligners.

Bias and Limitations

A limitation of the included studies is that despite the inclusion of a sufficient number of systematic reviews and meta-analyses that are of high scientific evidence, the number of randomized controlled trials is very limited. The lack of randomized controlled trials may lead to bias in the results and limits the overall validity of conclusions, calling for future high-quality trials to provide more robust conclusions.

CONCLUSION

Clear aligners produce clinically acceptable outcomes that could be comparable to fixed appliance therapy. Aligners facilitate oral hygiene practices which results in better periodontal health. However, it appears that Invisalign may not be as effective as fixed appliances in achieving certain tooth movements like vertical, radicular, and rotational movements.

DECLARATIONS SECTION

Ethics Approval and Consent to Participate: Not applicable.

Consent for Publication: Not applicable.

Availability of Supporting Data

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

DI: Study conception and design, TR: Data collection, RR: Analysis and interpretation of results, AF and AW: Draft manuscript preparation, TS and AA: Revised the text. All authors reviewed the results and approved the final version of the manuscript.

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Abbreviations: ARR: apical root resorption, ABO-OGS: American Board of Orthodontics Objective Grading System, ANS: anterior nasal spine, IPR: interproximal reduction, JBI: Joanna Briggs Institute, L1: lower central incisor, L6: lower first molar,

OIEARR: orthodontically induced external apical root resorption, PAR: peer assessment rating, PP: Palatal Plane, MP: Mandibular Plane, PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses, RCT: randomized controlled trial, TAD: temporary anchorage device, U1: upper central incisor, U6: upper first molar.

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