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Original Research Article

Dental Medicine

Efficiency of Aligners in Correcting Anterior Open Bite: A Systematic Literature Review

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Abstract

Background: The utilization of orthodontic aligners for treating various malocclusions has significantly increased in recent years. However, there is uncertainty regarding the evidence supporting their effectiveness in correcting anterior open bite. **Objective:** The purpose of this study was to systematically review the literature and evaluate the clinical effectiveness of clear aligners in correcting anterior open bite based on the available evidence. Materials and methods: A total of three databases (Pubmed, Sciences Direct and Google Scholar) were searched until March 2023, in addition to a manual search in the following journals: the American Journal of Orthodontics and Dentofacial Orthopedics, The Angle Orthodontist, and the European Journal of Orthodontics. Prospective and retrospective studies assessing the ability of aligners in achieving incisal extrusion and molar intrusion movements published during the last 10 years in English were eligible to be selected. Study selection and data extraction were undertaken independently by two reviewers. Risk-of-bias (RoB) assessment was evaluated using the study quality assessment tool of NHLBI, NIH. The reporting of this review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Results: Nineteen relevant articles were included in the analysis, comprising four prospective non-randomized and fifteen retrospective non-randomized studies. Among these, four studies compared the efficacy of aligners versus fixed appliances in correcting anterior open bite, while fourteen papers evaluated the overall effectiveness of aligners in treating this malocclusion. The risk of bias was categorized as high in one study, moderate in eight studies, and low in ten studies. Extrusion was found to be easily achievable with aligners, with the actual quantity of extrusion often surpassing predictions in the majority of studies. The mean reported extrusion amounted to 1.8mm. Additionally, the mean reported intrusion was 0.75mm. *Conclusion:* It is evident that aligners are an effective option for the treatment of anterior open bite, this effectiveness is achieved by combining the extrusion and palatal tipping of the anterior segments with the intrusion of the lateral segments, resulting in a counterclockwise rotation of the mandible. Moreover, aligner treatment may be a valid alternative to conventional orthodontic therapy, but it does not appear to provide better control over the vertical dimension compared to fixed orthodontic appliances in adult patients.

Keywords: Clear aligners, Invisible orthodontics, Anterior open-bite, Treatment outcomes, Extrusion, Intrusion, Vertical dimension.

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INTRODUCTION

In recent years, there has been a marked increase in the number of adult patients seeking orthodontic treatment. These patients express a preference for aesthetic and more comfortable alternatives compared to traditional fixed orthodontic appliances. In 1946, Kesling pioneered the idea of using transparent orthodontic appliances by developing the theory of employing a series of thermoplastic dental

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aligners to progressively move misaligned teeth to improved positions [1-3]. In 1997, Align Technology (Santa Clara, California), revolutionized orthodontics by introducing advanced 3D imaging technology to launch treatment with transparent aligners (Clear Aligner Therapy: CAT). This breakthrough transformed Kesling's initial concept into a viable orthodontic treatment option. Since then, CAT has become a trusted orthodontic procedure, recognized for its aesthetics and comfort, particularly appreciated by adult patients [4].

Initially, aligner therapy was employed to correct minor crowding or close diastemas. However, due to advances in aligner materials, attachment designs, and 3D software, it is now possible to treat various types of malocclusions [5]. The treatment of anterior open bite remains one of the most complex challenges faced by orthodontists today [6]. Poor dental and/or skeletal positioning leads to vertical inadequacy of the arches, preventing the teeth from occluding. This lack of contact can be caused either by a dentoalveolar anomaly or a skeletal anomaly, and the pathogenesis of anterior open bite will determine the choice of treatment. There is a wide range of treatment options, including maxillofacial surgery to correct skeletal origin open bite, intrusion of posterior segments to address open bite due to overeruption of posterior teeth, or extrusion of the anterior dental segment, especially in cases of insufficient vertical development of the premaxillary region [7].

More recently, some practitioners have started using aligners to control vertical dimension, raising the possibility of developing posterior open bites at the end of aligner treatment [8]. With the series of improvements (Invisalign G series) introduced in recent years, several clinical case reports using aligners have demonstrated good vertical control.In this context, we undertook this systematic review to evaluate the effectiveness of aligners in correcting anterior open bite. It is structured by four main sections: Introduction, Materials and Methods, Results, and Discussion (IMRaD structure).

2. MATERIELS AND METHODS 2.1 Eligibility Criteria

The PICOS (population, intervention, comparison, outcome, study design) format was used to formulate the clinical question with defined inclusion and exclusion criteria (Table 1). All articles included in this systematic review met the following criteria.

		•
Domains	Inclusion Criteria	Exclusion Criteria
Participants	Orthodontic patients of any age presenting with anterior open-	Studies involving syndromic patients,
	bite malocclusion	in vitro studies, studies with a very
		limited number of patients.
Intervention	Treatment with clear aligners	Orthognathic surgery treatment
Comparaison	Comparison using ClinCheck® models, cephalometric	
	superimpositions, clinical evaluation, PAR index and ICON	
	scores	
Outcome	Any effect on clinical efficiency, any manifestation of clinical	
	effectiveness in incisor extrusion or molar intrusion,	
	movement accuracy, or predicted toothmovement in	
	ClinCheck®	
Study design	Randomized controlled trials, or non-randomized trials,	Systematic review, Narrative review,
	retrospective studies, prospective studies, Finite Element	Non-original article, Letters to the
	Analysis	Editor, Case report, Case series

Table 1: Eligibility criteria

2.2 Information Sources and Search

Two reviewers independently conducted a comprehensive search using a combination of controlled vocabulary (MeSH) and free text terms. PubMed, Sciences Direct and Google Scholar were searched from January 2013 to March 2023. Only english articles were included. Keywords used in search were: "Clear aligners", "Invisible orthodontics", "Anterior open-bite", "Extrusion","Intrusion","Vertical dimension" (Table 2).

	Table 2: Details of the database search Database Search Strategy								
Database	Search Strategy								
Pubmed	Orthodontics AND ("orthodontic appliances, removable" OR "removable orthodontic appliances")								
	AND ("clear aligners" OR ("clear" AND "aligners") AND aligners AND ("therapy" OR								
	"treating") AND anterior AND ("OPEN" OR ("open" AND "bite") OR "open bite")								
Sciences Direct	Orthodontic AND aligner AND open bite								
Google Scholar	Orthodontic AND aligner AND open bite								
Manual search	Orthodontic AND aligner AND open bite								

Table 2: Details of the database searc	h Database Search Strategy
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2.3 Study Selection

The process of selecting studies was conducted independently and in duplicate. All pertinent articles were imported into Zotero, a bibliography generator. Initially, duplicate articles were eliminated. Subsequently, titles and abstracts were scrutinized for eligibility. Full-text reports were consulted for articles that appeared to meet the inclusion criteria. Ultimately, relevant articles were subject to comprehensive analysis

2.4 Data Collection Process and Items

Data from the chosen articles for this study were extracted using a predefined standardized form by two independent reviewers. The collected information included author, year, number of participants, intervention, outcomes, and author conclusions. In cases of doubt or disagreement between the two reviewers, resolution was achieved through discussion.

2.5 Risk of Bias of Individual Studies

The assessment of the risk of bias (RoB) in all pertinent studies utilized the NHLBI, NIH Study Quality Assessment Tool [9]. This tool is specifically crafted for the methodological evaluation of both retrospective and prospective studies. In the case of retrospective studies, it scrutinizes each study against twelve criteria, with responses categorized as 'Yes' for clear adherence, 'No' for clear non-compliance, and 'Uncertain' for inaccuracies. Subsequently, a score is assigned to each study, with those scoring above 8 classified as high-quality studies, scores below 6 indicating a high risk of bias, and scores between 6 and 8 denoting moderate quality. The same methodology is applied to prospective and cohort studies (14 criteria for cohort studies).

3. RESULTS

3.1 Study Selection

The results of the electronic search and the subsequent article selection process were visualized in the PRISMA flow diagram, aligning with PRISMA guidelines. Initially, 1266 studies were identified through both database and manual searches. Following the elimination of duplicates, 71 studies persisted, and only 26 advanced beyond the stage of title and abstract screening. Ultimately, 19 articles were included in the final selection, as depicted in the PRISMA flow diagram (Figure 1).



Fig-1: Flow chart according to the PRISMA statement

3.2 Study Characteristics

The research findings encompass thirteen retrospective studies, including two controlled studies, along with two cohort studies and four prospective studies. These nineteen studies, conducted between 2013 and 2023, reflect a growing interest in the subject, particularly evident in the eleven papers published from 2019 to March 2023. Notably, four of the studies within

this review specifically compared aligners with conventional orthodontic treatments for correcting anterior open bite. The investigations focused on two types of tooth movement: incisor extrusion and molar intrusion. In total, studies involved 924 patients, with sample sizes ranging from 27 [10] to 120 [11]. The participants, adults aged 19 to 55 years, exhibited full permanent dentition. The primary orthodontic appliances employed in these studies were clear aligners, predominantly the Invisalign® system.

3.3 Data Extraction and Synthesis

The nineteen articles included in this systematic review and the data extracted from each study are shown in Table 3.

Author	Year	Study Design	No of participants	Intervention	Outcomes	Conclusion
Xiao-Juan Zhang [12]	2015	Retrospective study	32 (28 M,4F) Mean age 26.7	-All patients were treated with the same brand of clear aligners.	- The difference between the predicted root position in the ClinCheck® and the actual position found is significant, and it is more pronounced in the mandible than in the maxilla.	-Crowns but not roots of anterior teeth can be moved to designated positions using clear aligners, because these appliances cause tooth movement by tilting motion.
Peter H. Buschang [10]	2015	Prospective study	27	Invisalign®	-The difference in occlusal relationships between the models is highly significant: p = 0.003.	-The ClinCheck models do not accurately reflect the patients' final occlusion, as measured by the OGS, at the end of active treatment.
Jiafeng Gu [13]	2017	Retrospective case-control study	96	2 groups: -Invisalign: 48 patients. -Fixed appliances: 48 patients. Using the PAR (Peer Assessment Aating) index, an assessment of documents (3D models, photos, radiographs) before and after treatment was conducted.	- No significant difference in post-treatment PAR scores, but the data indicates that fixed appliances are more effective than Invisalign in reducing PAR scores.	-Fixed appliances are more effective in improving malocclusion.
Roozbeh Khosravi [11]	2017	Retrospective study	120 (16M,84F) Mean age 33	 3 groups of patients treated with Invisalign: 68 : Normal overbite 40 : Deepbite 12 : Open Bite. 	-In patients with an open bite, there is a reduction of 1.5 mm in the overbite. The correction of the open bite is achieved through a movement of proclination of the upper and lower incisors.	 Treatment with Invisalign does not involve the intrusion of posterior teeth. Invisalign corrects mild to moderate anterior open bites.
CHUNG HOW KAU [14]	2017	Retrospective study	100 (classe I and classe II malocclusion)	Invisalign; 2 groups: -AOB : 23 -Control group : 77 A comparison of pre- treatment and post- treatment scores was conducted using the PAR index and ICON.	-No significant difference between the two groups in PAR index and ICON scores reduction : p > 0.05.	- The third generation of Invisalign can be equally successful in treating Class I and II malocclusions, whether with an anterior open bite or in cases without an anterior open bite.

Table 3: Overview of included studies

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Fan Daia [20]	Greg Huang [19]	Bella Shen Garnett [18]	Orfeas Charalampakis [17]	Shuka Moshiri [16]	Thorsten Grunheid [15]
	2019	2019	2018	2017	2017
sective study	Retrospective study	Retrospective study	Retrospective	Retrospective study	Cohort study
,26F) age : 19,4±6,3	91 orthodontistes And 347 patients.	53 (18M,35F) Mean age 34,5±9ans	20(3M,17F) Mean age <i>37</i>	30(8M,22F) Mean age 28,81	30(13M,17F) Mean age 21,6 ±9,8
lign achieved and predicted movements of the ary first molars and i incisors were red using a paired t-	Four main treatment groups were evaluated: aligners, fixed appliances, temporary anchorage devices (TADs), and orthognathic surgery.	2 groups: -Aligners: 36 -Fixed appliances:17. 13 measurements were calculated at T1 and T2 for both groups using lateral cephalometric radiographs.	Invisalign	Invisalign: A comparison of lateral cephalometric radiographs between pre- treatment (T1) and post- treatment (T2) was conducted.	Invisalign : The differences between the actual and predicted results were calculated and tested for each type of tooth.
listo-vestibular cusp of xillary first molar was ely stable, and the vestibular cusp vent a more significant on than predicted by - 0.89 mm. The central 's extruded more than - 1.17 mm compared to icipated changes.	- Aligners appear to be more recommended for patients with lingual issues.	-No significant difference in all variables between the two groups: $P > 0.05$ for all measurements. -The correction of the overbite is slightly better with aligners (2.3 mm) than with fixed appliances (1.6 mm).	- No significant difference in the vertical movement of all teeth between the predicted and obtained model.	 A statistically significant difference is found in 9 out of 12 variables. Extrusion of upper incisors by 0.5 mm and lower incisors by 0.8 mm. Intrusion of upper molars by 0.4 mm and lower molars by 0.6 mm. 	The maxillary central incisor and lower incisors underwent a more significant proclination than predicted in the ClinCheck®.
ary anchorage devices, ridges, attachment , and overcorrection I be considered to aid in ing the predicted es.	The increased recommendation of aligners was associated with white and Asian patients, the presence of lingual posture issues, and female practitioners.	- Significant lingual inclination of the upper and lower incisors, good vertical control, and no posterior tooth proclination appear to be the main mechanisms for correcting the open bite.	-The achieved proclination of maxillary and mandibular incisors and maxillary canines is greater than the movement predicted in the ClinCheck®. The vertical movement of maxillary canines is more predictable than that of mandibular canines.	-The closure of the open bite was mainly achieved through a combination of counterclockwise rotation of the mandibular plane, intrusion of the lower molars, and proclination of the lower incisors.	-The mandibular incisors, as well as the maxillary central incisors, tend to be positioned more occlusally than predicted.

Kayla Harris [21]	2020	Retrospective study	45(4M,41F) Mean age 30,73±8	 3 groups based on the severity of the open bite (mild, moderate, severe) and according to skeletal severity: based on the angle of the initial mandibular plane. 18 measurements before and after treatment were calculated. 	Change in overbite = 3.27 ± 1.09 mm. A significant extrusion of the upper and lower incisors. A significant intrusion of the maxillary and mandibular first molars in all patients.	The closure of the open bite with aligners occurred through a combination of maxillary and mandibular incisor extrusion, maxillary and mandibular molar intrusion, resulting in mandibular autorotation
Nada Haouili [27]	2020	Prospective study	38(13M,25F) Mean age 36	Invisalign (Classe I - 22, Classe II) =13,Classe III=3).	 The accuracy of maxillary central incisor extrusion is thighest: 56%. The use of optimiz attachments and powridges improved the accuracy of the movement. 	A significant improvement in the accuracy of maxillar incisor proclination. Invisalign is more effective in correctir open bites than deepbites.
Hailee RASK [23]	2021	Retrospective study	66(23M,43F)	2 groups: -Invisalign : 44 -Fixed appliances:22. A comparison of the following measurements was conducted: OB, SN_MP, FMA, L6H, U6H, PP_MP, LFH, TFH, Posterior_OB.	Overbite (OB): decreased by 1.15 mm in patients treated with fixed appliances and remained almost the same in patients treated with Invisalign.	The treatment with aligners did not provide better control of the vertical dimension than the treatment with fixed appliances in adult patients.
Sivaporn Sachdev [24]	2021	Prospective study	30(10M,20F) Mean age : 31,8 ans.	Six types of movements have been studied, namely vestibuloversion, linguoversion, mesiodistal movement, intrusion, extrusion, and rotation.	Significant difference between expected and achieved anterior teeth extrusion (P<0.01).	The least accurate movement isintrusion (43.28%), followed by extrusion.
Heeyeon Suh [25]	2022	Retrospective study	 69 : -50: skeletal open bite. -19: dental open bite. 3 groups: -Classe I=44, -Classe II = 16, -Classe III = 9 . 	15 cephalometric measurements were calculated before (T1) and after (T2) the treatment. The paired t-test was employed to assess cephalometric changes.	A positive OB was obtained in 94% of patients. The average change in OB was 3.3 ± 1.4 mm. The amount of maxillary molar intrusion is similar in Class I and II groups. No maxillary molar intrusion was observed in the Class III group.	The aligners alone can allow for a limited but consistent maxillary molar intrusion while maintaining the vertical position of mandibular molars. This provides reasonable vertical control.
Michaela Pokorná [26]	2022	Etude rétrospective	30(19M,11F) Mean age 20	21 parameters (were evaluated on cephalometric radiographs taken before (T1) and after treatment (T2).	statistically significant increase in the OB with an average of 2.71 mm. Significant extrusion of maxillary and mzndibular incisor (average 0.95 mm and 0.38mm respectively).	The clinical effect of open bite closure is attributed to a combination of lateral segment intrusion, incisor extrusion, and lingual inclination of the anterior segments.

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Tommaso Castroforio [28]	Brett Peter Steele [27]
2023	2022
Prospective study	Cohort study
79(23M,56F)	53
Clear aligner therapy	Invisalign: 29 Fixed appliances + MSPI: 24. 9 linear measurements (OB,OJ,PP- U1,Pp-L1,PP-U6,L6-MP,ANS- Me,Upper anterior face height,VRL- Pog), and 11 angular measurements (SNA,SNB,ANBU1-PP,L1-Mp,SN- OP,Mp-SN,Palatal plane angle,Facial angle) have been compared between the two groups.
The difference between the obtained and expected results is significant in terms of vertical translational movement, and this is observed across all teeth (P < 0.001).	Maxillary and mandibular incisor extrusion is more significant with Invisalign. OB reduction is more important with MSPI than Invisalign. Maxillary molar intrusion is more substantial with MSPI: $U6 = 1.8$ mm, and $L6 = 0.7$ mm.
The movements of the second molars are mostly unspecified: research on thermoplastic materials that can control these movements needs to be strengthenedThe pattern of aligner changes should be defined based on the desired movement.	MSPI corrects anterior open bite through maxillary molar intrusion and mandibular autorotation. In contrast, Invisalign corrects open bite through incisor extrusion.

3.4 Risk of Bias in Included Studies

The quality of evidence of the included studies was evaluated by the NHLBI, NIH Study Quality Assessment Tool. Out of them, ten studies [28, 17, 13, 21, 11, 16, 23, 24, 27] were classified as high quality. Eight articles [10, 20, 18, 15, 22, 19, 25, 12] were deemed to have moderate quality, and one article [14] was assessed as low quality.

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	1	2	3	4	5	6	7	8	9	10	11	12	Rating
[12]	Y	Y	Y	Y	Х	Y	Y	Х	U	Y	Х	U	Moderate
[13]	Y	Y	Y	Y	Х	Y	Y	Y	Х	Y	Y	Y	Good
[16]	Y	Y	Y	Y	Х	Y	Y	Y	Х	Y	Х	Y	Good
[17]	Y	Y	Y	Y	Х	Y	Y	Y	U	Y	Y	Y	Good
[18]	Y	Y	Y	Y	Х	Y	Y	Y	U	Y	Х	Х	Moderate
[19]	Y	Y	Y	Y	Х	Y	Y	Х	Y	Y	Х	Х	Moderate
[20]	Y	Y	Y	Y	Х	Y	Y	U	Х	Y	Х	Х	Moderate
[21]	Y	Y	Y	Y	Х	Y	Y	Y	U	Y	Y	Y	Good
[23]	Y	Y	Y	Y	Х	Y	Y	Y	U	Y	Y	Y	Good
[25]	Y	Y	Y	Y	Χ	Y	Y	Y	U	Y	Х	Х	Moderate
[26]	Y	Y	Y	Y	Χ	Y	Y	Y	U	Y	Y	Y	Good
[11]	Y	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Х	Good
[14]	Χ	Y	Х	Y	Y	Y	Х	U	Y	Х	Х	Х	Mauvais
[10]	Y	Χ	Y	Y	Χ	Y	Y	Y	Х	Y	Х	Х	Moderate
[22]	Y	Y	Y	Y	U	Y	Y	Y	Х	Y	Х	Х	Moderate
[24]	Y	Y	Y	Y	Χ	Y	Y	U	U	Y	Χ	Y	Good
[28]	Y	Y	Y	Y	Y	Y	Χ	Y	Х	Y	Y	Y	Good
				* *	* *	**		* *	* *				

 Table 4: RoB assessment of the included studies

Y= Yes; X= No; U= Uncertain

Table 5: RoB assessment for studies

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Rating
[15]	Y	Y	Y	Y	Х	Y	Y	Х	Y	Y	Y	Y	U	Х	Moderate
[27]	Y	Y	Y	Y	Y	Y	Х	Y	Y	Х	Y	Y	Y	Y	Good

3.5 Certainly assessment:

The level of scientific evidence of each of the included studies was determined using the criteria

established by the Oxford Center for Evidence-based Medicine, as shown in Table 6. The nineteen articles were deemed to be of evidence level B. Consequently, conclusions of a moderate level of evidence could be drawn from the review process. This suggests a moderate

level of confidence in the results and conclusions derived from the review process.

	Table 6: level of sci	ientific evidence					
Reference	Level of evidence	Grade of recommendation					
[12]	2c	В					
[13]	2c	В					
[16]	2c	В					
[17]	2c	В					
[18]	2c	В					
[19]	2c	В					
[20]	2c	В					
[21]	2c	В					
[23]	2c	В					
[25]	2c	В					
[26]	2c	В					
[11]	3a	В					
[14]	3a	В					
[10]	2c	В					
[22]	2c	В					
[24]	2c	В					
[28]	2c	В					
[15]	2b	В					
[27]	2b	В					

4. DISCUSSION

4.1 Summary of Evidence

Up until 2009, according to a prospective study conducted by Kravitz *et al.*, [29] evaluating the accuracy of dental movements with aligners, extrusion was the least precise dental movement with aligners, achieving only 29.6% of the planned movement. Specifically, the extrusion of the maxillary central incisor proved to be the most challenging (18.3%), followed closely by the mandibular central incisor (24.5%). On average, extrusion measured 0.56 mm.

They explained that the difficulty of this movement was likely due to the aligner's inability to fully encompass the tooth during vertical traction. On the contrary, Boyd [30] reported that absolute extrusion is always challenging even with attachments. He advocates for extruding the teeth using elastics from buttons attached to the vestibular surfaces of the teeth and combining extrusion with movements more easily achieved with aligners, such as lingual version.

Indeed, there should be sufficient space next to the tooth to be moved to allow for its extrusion [31, 32]. This can be achieved through interproximal enamel reduction [33]. Attempting extrusion with insufficient space next to the tooth may lead to iatrogenic intrusion. Furthermore, this additional space increases the contact surface between the tooth and the aligner [34, 35].

A series of studies was conducted to investigate the ability of aligners in correcting anterior open bite, whether through extrusion of anterior teeth or intrusion of posterior teeth. One of the most promising outcomes of these studies was the improvement in the accuracy of anterior teeth extrusion.

Four studies included in this review reported greater dental extrusion than initially planned in the ClinCheck®; citing the study by Michaela Pokorná *et al.*, [26], which compared 21 parameters before and after treatment. They observed significant extrusion of maxillary incisors (average 0.95 mm) and mandibular incisors (average 0.38 mm). The measured values were higher than those predicted in the ClinCheck®. They concluded that aligners can be reliably used to treat mild open bites, and the clinical effect of closing the open bite is due to a combination of posterior intrusion, incisor extrusion, and lingual version of the anterior segments.

Khosravi *et al.*, [11] conducted a study involving 120 patients. They focused on managing vertical dimension using Invisalign. Their study revealed a reduction in anterior open bite of 1.5 mm in patients with anterior open bite, achieved through extrusion of the upper and lower incisors. Consequently, they concluded that Invisalign was effective in correcting mild to moderate anterior open bites.

The study by Moshiri *et al.*, [16] revealed that the correction of anterior open bite was primarily achieved through a combination of factors, including a counterclockwise rotation of the mandibular plane, intrusion of the lower molars, and extrusion of the lower incisors.

Furthermore, it is important to note that closing the anterior open bite by extruding the anterior teeth may

not be indicated for all adult patients with an anterior open bite. Additionally, maxillary incisor extrusion is considered unstable [36]. Some researchers believe that maxillary incisor extrusion in adult patients may compromise periodontal structures, lead to root resorption, and jeopardize smile aesthetics [37].

conclusion, our systematic In review demonstrates that aligners are effective in achieving incisor extrusion. However, it is important to note that a previous systematic review by Rossini et al., in 2014 [38] concluded that the use of aligners was not the recommended method for treating anterior open bite cases. Their study revealed that the accuracy of aligners in vertical movements ranged from 30% to 41% compared to the planned movement, and incisor extrusion, in particular, was the least accurate movement to achieve with aligners, with an average extrusion of 0.56 mm.

Aligners have proven to be particularly effective in the movement of incisor extrusion, and they can also allow for limited but consistent maxillary molar intrusion thanks to the "bite block effect" associated with masticatory forces.

In a prospective study conducted by Sivaporn Sachdev *et al.*, [24]. Results revealed that dental intrusion was the least accurate movement, with a precision of only 43.28%, followed by extrusion. Furthermore, it was observed that the incorporation of attachments significantly improved the precision of the results by enhancing aligner retention.

In another study conducted by Garnett *et al.*, [25], 69 adult patients with an anterior open bite were divided into three groups based on Angle class.

Results showed that the amount of maxillary molar intrusion is similar in Class I and Class II groups (0.39 and 0.56 mm respectively), and no maxillary molar intrusion was observed in the Class III group. Also, the maxillary molar intrusion coefficient in this study was similar to that of previous studies, which demonstrated an increase in overbite of 1.5 mm [39] and 1.2 mm [40] per 1 mm of additional maxillary molar intrusion.

A previous study by Moshiri *et al.*, [16] had reported a maxillary molar intrusion of 0.4 mm, in accordance with the earlier study, and that of the lower molars was 0.6 mm with aligners. They found that the improvements in the vertical dimension observed in this study are similar to those seen after molar intrusion with Temporary Anchorage Devices (TADs), i.e., the reduction of the occlusal plane angle, mandibular plane angle, and lower anterior facial height [41, 37].

In conclusion, the amount of posterior intrusion can vary from less than 0.5 mm to a maximum of 1 mm. Beyond this amount, the addition of Temporary Anchorage Devices (TADs) is necessary. Therefore, our results are in correlation with the review by Rossini *et al.*, [38], where they reported that the achieved amount of intrusion was 0.72 millimeters.

A study conducted by Garnett et al., [18] compared the effects of aligners and traditional fixed orthodontic appliances on correcting anterior open bites in adults. The results showed that there was no statistically significant difference in the extent of anterior open bite correction and the observed changes in various cephalometric measures of vertical control. However, the group treated with aligners exhibited a slight increase in lower incisor extrusion. Additionally, the correction of overbite was slightly better with aligners (2.3 mm) compared to fixed appliances (1.6 mm). The primary mechanism for correcting the anterior open bite was similar between the two treatment groups, involving lingual version of the upper and lower incisors while maintaining the vertical position of the upper and lower molars.

Regarding the treatment duration, the four comparative studies included in our review consistently concluded that aligners lead to a reduction in treatment duration by approximately 30% compared to traditional fixed orthodontic appliances [13].

4.2 Limitations

Our systematic review noted that most studies had a moderate level of evidence. The main sources of bias identified were related to the design of included studies, which were primarily prospective or retrospective studies, the lack of adequate blinding procedures, the absence of sample randomization, small sample sizes, and a low proportion of studies with control groups.

Additionally, our article selection was limited to studies available online and accessible for free, as well as those published or translated into English. This approach might have excluded relevant scientific studies published in other languages, posing a selection bias.

5. CONCLUSION

In conclusion, it is evident that aligners are an effective option for treating anterior open bite. This effectiveness is achieved by combining the extrusion and lingual tipping of the anterior segments with the intrusion of the lateral segments, causing a counterclockwise rotation of the occlusal plane and a counterclockwise rotation of the mandible. So, aligner treatment may be a viable alternative to conventional orthodontic treatment, but it does not appear to offer better control of vertical dimension compared to fixed orthodontic appliances in adult patients. However, due to the lack of randomized clinical trials, reaching definitive conclusions is additional challenging. Therefore, clinical and experimental research is needed to statistically evaluate

the long-term stability of occlusion and skeletal relationships in such treatments.

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Consent for publication: Not applicable

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