Efficacy of Clear Aligners in Correcting Anterior Open Bite- A Systematic Review

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Abstract

Objective:The aim was to systematically search the literature and assess the available evidence regarding theclinical effectiveness of clear aligners in correcting anterior open bite.

Materials and Methods:PubMed, PubMed Central, MEDLINE, Embase, National Library of Medicine, Cochrane Library, Web of Knowledge, and LILACS were searched electronically to identify all peer-reviewed articles till date potentially relevant to the review.The reference lists of all eligible articles were examined for additional studies. Additional manual search was also conducted in many orthodontic journals of interest, and unpublished articles were also searched for. To rate the methodological quality of the selected articles, a grading system described by the Swedish Council on Technology Assessment in Health Care was used.

Results:Ten relevant articles were selected to be included in this systematic review. According to the SBU tool, among the selected studies, the methodological quality was moderate for four studies and limited for the others. Thus, conclusions with a limited level of evidence could be arrived at from the review process. The most recurrent sources of bias were related to the study design, lack of blinding procedure, the sample size, and the lack of control group. However, there was substantial consistency among studies that clear aligner therapy is a viable option to correct anterior open-bite.

Conclusion:No definite conclusion could be derived due to the heterogeneity of the studies. Due to the limitations of this study, further clinical and experimental research is needed to statistically assess long-term stability of occlusion and skeletal relationships in treated open-bite cases.

Keywords: *Clear aligners, Invisible orthodontics, Anterior open-bite, Treatment outcomes.*

Introduction

A growing number of adult patients have sought orthodontic treatment in the last few years and have demonstrated a preference for esthetic and comfortable alternatives to conventional fixed orthodontic appliances.[1][2]Kesling introduced the idea of using transparent overlay orthodontic appliances in 1946 when he developed the theory of using a series of thermoplastic tooth positioners to transfer malaligned teeth slowly to better positions.[3] In 1997, Align Technology © (Santa Clara, Calif) adapted and implemented advanced 3D imaging technology to introduce clear aligner treatment(CAT), making the idea of Kesling a viable orthodontic treatment option.[4] Ever since then, CAT has been regarded as a reliable, esthetic, and comfortable orthodontic procedure for adult patients.

Orthodontic treatment of open bite remains one of the most challenging tasks faced by orthodontists today.[5] The vertical incompetence of the arches due to poor dental and/or skeletal position does not permit correct occlusion between antagonistic teeth. This lack of contact can be caused either by dentoalveolar or skeletal anomaly, and the pathogenesis of open bite will determine the course of treatment, whether orthodontic or combined surgical and orthodontic. Solely orthodontic intervention is an option only in cases of dentoalveolar

alteration, whereas surgery is indicated in cases of skeletal dysgnathia.[6]

Many factors may be responsible for an anterior open bite, including bad habits such as thumb-sucking, prolonged use of pacifiers, lip or tongue habits, or unfavorable growth patterns, which are often correlated with a genetic or familial predisposition. Excessive development of the lymphatic tissues (adenoid facies) causing airway obstruction, may also be responsible.[7] In general, the etiology of this type of malocclusion is multifactorial.[8] In the case of growing patients in whom bad habits have contributed to anterior open bite, early intervention with interceptive functional appliances or speech therapy may resolve or improve the clinical scenario.

In adult patients, on the other hand, accurate diagnosis of the dentoalveolar or skeletal origin of the malocclusion, via cephalometric analysis needs to be performed. In these cases, treatment options are numerous and involve maxillofacial surgery to correct skeletal open bite, intrusion of the posterior segments to correct dental open bite due to over-extrusion of the posterior segments; or extrusion of the anterior dental segment alone, especially in cases of poor vertical development of the premaxillary region.[9]

A systematic review by Rossini et al., which evaluated the efficacy of CAT in controlling various types of orthodontic tooth movements showed that extrusion was the most difficult movement to achieve, with maxillary and the mandibular central incisors showing the lowest accuracy.[10]

The present systematic review was undertaken to update the knowledge of the available evidence about CAT and to answer the following clinical research question: "Is CAT effective in correcting anterior open-bite?"

Materials and Methods

A systematic search was performed of articles published till date in thefollowing databases: PubMed, PubMed Central, MEDLINE, Embase, National Library of Medicine, Cochrane Library,Web of Knowledge, and LILACS.The search strategy comprised use of the followingterms; Orthodontics AND ("orthodontic appliances, removable" OR ("orthodontic" AND "appliances" AND "removable") OR "removable orthodontic appliances" OR "invisalign") AND ("clear aligners" OR ("clear" AND "aligners") OR "clear" OR "transparent") AND aligners AND ("therapy" OR "treating") AND anteriorAND ("OPEN" OR ("open" AND "bite") OR "open bite").Additionally, a manual search was conducted in orthodonticjournals of interest, such as the American Journalof Orthodontics, European Journal of Orthodontics,The Angle Orthodontist, Journal of Orthodontics and Journalof Clinical Orthodontics.In addition, unublished studieslistedin the national clinical trials database ClinicalTrials.gov(www.clinicaltrials.gov) and the National Research Register(www.controlled-trials.com), were searched with theterms "clear aligners" or "Invisalign."Based on the abstract data, we completed the initial selection process independently, then resolved any differences through discussion.We selected andcollected all the articles that appeared to meetthe initial inclusion criteria based on theirabstracts.In cases in which specific data were necessaryfor the discussion and was not specified in theabstract, we made efforts to contact the authorsto obtain the required extra information.The reference lists of these articles were perused,and references related to the articles were followed up. Duplicate articles were eliminated, and the studies wereselected for inclusion.

Studies on orthodontic treatment with clear aligners for treating open-bite cases were included in the study. Studies on patients with genetic syndrome and severe facial malformations, studies using clear aligners for malocclusions other than open-bite, in-vitro studies, studies with surgical orthodontic techniques, review articles and author debates were excluded. The 'PICOS' approach was used to extract data fromthe selected articles. PICOS stands for ''population(participants), intervention (or exposure for observationalstudies), comparator, outcomes and studydesign''.

Population: Orthodontic patients of any age presenting with anterior open-bite malocclusion.

Intervention: Treatment with clear aligners.

Comparator:Comparison using ClinCheck® models, cephalometric superimpositions, clinical evaluation, PAR index and ICON scores.

Outcomes: Any effect on clinical efficiency, treatmentoutcomes, movement accuracy, or predicted toothmovement in ClinCheck®, includingchanges in alignment or occlusion, treatmentduration, and completion rate, as primary outcomes.

Studydesign: Randomized or non-randomized prospective or retrospective studies, clinical trials.

Results

Ten relevant publications were included in the study after screening and checking for eligibility, out of which three were retrospective non-randomized studies and one was a prospective non-randomized study.The remaining data obtained was from case reports.

According to the SBU tool, among the selected studies, the methodological quality was moderate for four studiesand limited for the others.Thus, conclusions with a limited level of evidence could be arrived at from the review process. The most recurrent sources of bias were related to the study design, lack of blinding procedure, the sample size, and the lack of control group.

Swedish Council on Technology Assessment in HealthCare (SBU) Criteria for Grading Assessed Studies

Grade A—high value of evidence

All criteria should be met:

Randomized clinical study or a prospective study with a well-defined control group

Defined diagnosis and endpoints

Diagnostic reliability tests and reproducibility tests described

Blinded outcome assessment

Grade B—moderate value of evidence

All criteria should be met:

Cohort study or retrospective case series with defined control

or reference group

Defined diagnosis and endpoints

Diagnostic reliability tests and reproducibility tests described

Grade C—low value of evidence

One or more of the conditions below:

Large attrition

Unclear diagnosis and endpoints

Poorly defined patient material

Grading of Selected Studies

Study (Author, Year)	Grade
Kravitz et al., 2009	B
Park et al., 2009	C
Schupp et al., 2010	C
Guarneri et al., 2013	C
Bowman et al., 2015	C
Wheeler et al., 2016	C
Kau et al., 2017	B
Giancotti et al., 2017	C
Moshiri et al., 2017	B
Garnett et al., 2018	B

Definitions of Evidence Level

Level	Evidence	Definition
1	Strong	At least two studies assessed with level ‘‘A’’
2	Moderate	One study with level ‘‘A’’ and at least two studies with level ‘‘B’’
3	Limited	At least two studies with level ‘‘B’’
4	Inconclusive	Fewer than two studies with level ‘‘B’’

The study design, participants, type of intervention, and observations of the qualitative analysis is given in the table

Discussion

The present systematic review showed that the use of clear aligners is recommended in treating anterior open bite. However, literature has shown that extrusion is the least accurate tooth movement to perform with clear aligners. [10][11][12]

Rossini et al [10]when evaluating the efficacy of clear aligners in controlling orthodontic tooth movement, found that clear aligner technique is not recommended to treat open bite. Open bite is a challenging malocclusion to treat, with a high incidence of relapse. Extrusion being the least accurate tooth movement to perform with CAT, it can result in larger deviations compared to other movements. This lack of efficiency could be due to the appliance’s difficulty in producing sufficient force to substantially extrude the teeth.

Papadimitriou and his colleagues, in their systematic review recommended CAT for treating mild to moderate open bite mainly though incisor extrusion.[11] This is also in agreeance with another systematic review by Galan-Lopez et al, in which the mandibular plane angle remained constant while attempting incisor extrusion by CAT.[12] While these systematic reviews focussed on comparing the clinical effectiveness of CAT in effecting various tooth movements, we incorporated studies that studied exclusively its efficiency in effecting tooth movements in correcting anterior open bite.

In one prospective study [13], comprising of 401 anterior teeth treated with anterior Invisalign, theleast accurate tooth movements were extrusion of themaxillary (18.3%) and mandibular (24.5%) centralincisors. The maxillary lateral incisors were the most commonly extruded teeth (n = 23). Only 13 of the 64 teeth had attempted extrusions greater than 1.0 mm (range, 1.0-1.8 mm), and no tooth had an attempted extrusion greater than 2 mm. The average amount of extrusion attempted was 0.56 mm. The difficulty in extrusive movement was most likely because the aligner poorly grasped the tooth during vertical pull. Boyd[14] stated that even with attachments, absolute extrusion remains difficult and recommended the extrusion of teeth with an elastic button on the facial aspect of the tooth.Alternatively, the clinician could consider combining extrusion with more accuratemovements such as retraction (lingual constriction) or retroclination to bring about relative extrusion.

Park et al, [15] in his case report series, utilised intermaxillary and intramaxillary elastics with CAT to correct open bite when minor extrusions (2-3mm) are required. The use of clear aligners with intermaxillary elastics is known as Cow-Catch aligners. To fabricate this, once a working cast is produced, the teeth on this cast are ideally set-up (extruded) before forming the aligners by pressure-moulding or vacuum-forming. The teeth to be extruded are supplied with buttons and connected to the opposite arch with elastics where buttons were attached to the aligner. When the expected

extrusion is achieved, the respective teeth will contact the inner surface of the aligner so that no additional extrusion occurs. Thus, it is a fail-safe appliance. If a patient cannot tolerate the limited mouth opening while wearing Cow-Catch aligners with intermaxillary elastics or needs to interact a lot verbally, it is recommendedthat an appliance modification can be done. The modified Cow-Catch aligners uses intramaxillary elastics and is characterized by buttons on the labial surface of the teeth and lingual side of the aligner on the same tooth. This type of aligner is moreconvenient and comfortable for allpatients because it allows a more normalfunction. According to the authors, with good cooperation, the intended treatment is achieved within 6 to 8 weeks, provided the patient wears the elastics for atleast 17 hours a day.

Schupp et al [16] also published two anterior open bite cases successfully treated with Invisalign alone. Vertical rectangular bonded attachments were used to extrude the teeth. In 17-20 months, anterior bite closure was achieved with proper overbite and overjet, well aligned anterior teeth, and canine guidance was achieved on both sides, closely matching the projections of ClinCheck. Post-treatment stability of closed bite was good.

In a case report by Guarneri et al [17], successful closure of a 4mm anterior open bite was achieved. Extrusion of upper incisors was achieved by bevelled horizontal rectangular bonded attachments and ellipsoid attachments for the lower incisors. Interproximal reduction of upper anteriors were done to correct the crowding. The extrusion rate was 0.12 mm per aligner, on the upper incisors for a maximum of 3 mm and on the lower incisors for 1 mm. The treatment was completed with full patient satisfaction after 18 months.

The difficulties encountered in bringing about extrusion and strategies to control them have been proposed by Nicozisis [18] and Humber [19]. They suggested use of bonded attachments, elastics, detailing pliers such as Clear Collections' The Vertical to accentuate couple, overcorrection, supracrestal fiberotomy (Edwards procedure) and long-term fixed retention to prevent relapse. [20][21][22][23] There should be sufficient space adjacent to the affected tooth in order to extrude it. This can be achieved by interproximal reduction. If extrusion is attempted with insufficient adjacent space, iatrogenic intrusion may occur as the tooth is inadvertently "squeezed" apically. Space opening also increases the tooth-surface area for the plastic to contact—an important consideration with a small, blade-shaped lateral incisor. Aligner Chewies have been designed to address inadequate tracking or "aligner lag."[24] Even with the best clear-aligner biomechanics preparation, aligner lag or tracking error of individual teeth may still occur, often due to less than optimal patient compliance with aligner wear. Adjunct elastics may be added to assist in extruding selected teeth into the aligner trays. Bonded buttons on the facial, lingual, or both surfaces of the lagging tooth are attached with "bootstrap" elastics at the gingival margin. [25] Anorthodontic elastic is stretched across the incisal surface of the seated aligner to the button, thusextruding or dragging the tooth into the tray. The gingival margin of the aligner plastic must be cutto avoid the buttons, so that the tray can seat completely. Alternatively, to avoid the need for a buttonon the facial side of the tooth, elastic hooks can be cut into the aligner tray using TearDrop plier.

Passive posterior intrusion is a common matter in question in clear-aligner treatment. Posterior plastic may be removed to allow the posterior teeth to be spontaneously settled or erupted into occlusion, and intermaxillary elastics may also be used for forced eruption.Clever methods for using clear aligners to refine the closure of anterior open bites by intrusion of posterior teeth have been suggested by Boyd[26] and Dayan[27]. The underlying concept is to harness the aligners' propensity to produce an iatrogenic posterior open bite simply as a result of holding plastic between the teeth for extended periods of time. One such strategy involves sequential intrusion of specific posterior teeth while maintaining or extruding the anterior teeth, thus creating a deeper curve of Spee [27]. Using Chewies to exert intrusive forces on targeted posterior teeth can improve the predictability of this method. An article by Bowman et al [28] shows open bite cases successfully treated using these mechanisms. This concept of employing a combination of anterior extrusion and posterior intrusion to correct anterior open bites was also mentioned in Wheeler's article [29]. The addition of miniscrew anchorage to support biomechanics involving elastic forces for the extrusion of anterior or posterior teeth is another logical extension of their application to clear-aligner treatment. Miniscrews are

used as an adjunctwith bootstrap mechanics to increase the reliability of posterior intrusion and potentially produce spontaneous mandibular autorotation. With the need to extrude anterior teeth during anterior open bite correction, Lin and colleagues have identified the combination of clear aligners with miniscrew anchorage for such treatment. [30]

Giancotti et al [31] in his case report series established that aligners allow an optimal vertical control and can determine molar intrusion by bite-block effect of two layers of aligner material between the dentition for 22 hours/day for 18–24 months and thereby subsequent minimal autorotation of the mandible and improvement of skeletal open bite. In case minimal molar intrusion is needed (1–2 mm), the vertical dimension would also be well controlled, not tending to worsen. In addition, aligners are also able to extrude the incisors by means of appropriate attachments and allow a minimal dental correction of the open bite.

One retrospective study [32] compared the pre-treatment difficulty of 100 cases treated with Invisalign with the post-treatment outcomes, as measured by the Peer Assessment Rating (PAR) index and the Index of Complexity, Outcome, and Need (ICON). The average PAR index scores of the anterioropen-bite patients (23 cases) were 21.9 ± 8.6 pre-treatment and 4.5 ± 4.0 post-treatment, for areduction percentage of 76.7% ± 18.0%also a "great improvement". The average ICON scoresfor the anterior open-bite cases were 57.4 ± 19.2 pre-treatment and 16.6 ± 5.7 post-treatment, for an improvement of −9.0 ± 30.3—still "substantially improved". When the anterior open-bite cases were compared to the control group (77 cases), their average pre- and post-treatment PAR and ICON scores, reduction percentages, and improvement grades were statistically similar. Thus, this study concluded with favourable results for anterior open-bite cases.

We found two retrospective studies that used cephalometrics as means of evaluation of treating anterior open bite cases using CAT [33][34]. Moshiri et al [33] compared pre-treatment and post-treatment lateralcephalograms of 30 adult patients with anterior open bite treated using Invisalign. The following vertical measurements were considered: SN to maxillary occlusal plane (SN-MxOP), SN to mandibular occlusal plane (SN-MnOP), mandibular plane to mandibular occlusal plane (MP-MnOP), SN to mandibular plane (SN-MP), SN to palatal plane (SN-PP), SN to gonion-gnathion plane (SN-GoGn), upper 1 tip to palatal plane (U1-PP), lower 1 tip to mandibular plane (L1-MP), mesiobuccal cusp of upper 6 to palatal plane (U6-PP), mesiobuccal cusp of lower 6 to mandibular plane (L6-MP), lower anterior facial height (LAFH), and overbite (OB). Statistically significantdifferences were found in overall treatment changes for SN-MxOP, SN-MnOP, MP-MnOP, SN-MP, SN-GoGn, L1-MP, L6-MP, LAFH, and OB. But SN-PP, U1-PP, and U6-PP did not undergo any statistically significant changes. Thus, bite closure was mainly achieved by a combination of counter-clockwise rotation of the mandibular plane, lower molar intrusion and lower incisor extrusion. Garnett et al [34] did a cephalometric comparison between clear aligners and fixed appliances in correcting adult open bite. It was found that there was no statistical difference in the magnitude of overbite correction and the changes in any of the vertical control cephalometric measurements. The clear aligner group showed an increased amount of lower incisor extrusion to a small degree. The main mechanism of open bite correction was similar between the two treatment groups and was accomplished by retroclining the upper and lower incisors while retaining the vertical position of the upper and lower molars.

In our systematic review, majority of studies presented withlow level of evidence. Very strong limitations were the absence of proper control groups, the absence of proper blinding procedures, the lack of sample randomization procedures, and the small sample sizes. One study employed malocclusion scoring scales, such as the PAR index, which presents limitations, mainly related to the generic weighting system.

Considering all the results of this systematic review it is recommended that future researchers in this fieldshould include RCTs with rigorous methodology and proper sample size in order to increase the power ofthe studies for estimating the effects. Only with this knowledge will it be possible to establish defined CATtreatment protocols for routine clinical practice.

Conclusion

Orthodontic treatment in patients with open bite can be resolved efficiently by using clear aligners

whilesimultaneously maintaining facial aesthetics. Proper diagnosis and treatment planning is a key element in achieving the desirable outcome. By means of anterior extrusion or posterior intrusion or a combination of both, clear aligners have been successful in treating anterior open bite. Some aspects inherent to the biomechanics of aligners, such as the vertical control and possible mandible counter clockwise rotation, have positive effects on the anterior open bite correction. As no randomized control trials were done in this topic, we cannot derive at a strong level of conclusion. Further clinical and experimental research is needed to statistically assess long-term stability of occlusion and skeletal relationships in such types of treatment.

Ethical Clearance – Not required since it is a review article

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