

Class II correction using clear aligners: a scoping review

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Introduction: The increase in popularity and demand for clear aligner therapy (CAT) has resulted in the recent use of this modality to treat more complex orthodontic cases.

Aim: This scoping review aims to collate CAT treatment approaches for the correction of Class II malocclusions.

Methods: Six databases along with grey literature sources were searched using key terms related to "Class II malocclusions" and "clear aligners." Duplicates were removed and two independent reviewers screened the titles and abstracts before data from the included full-text articles was extracted into a structured recording form. The data were summarised narratively.

Results: The search yielded 2271 studies of which 123 were suitable for full-text review and a total of 59 studies were subsequently included in the present final review. In growing individuals, a combination of CAT with or without mandibular advancement (MA) components and/or elastics was assessed. For non-growing individuals, sequential distalisation and general alignment of the arches (with or without elastics) were common treatment approaches. The benefits of CAT for Class II correction were noted to be concurrent alignment plus good incisor and vertical control. The limitations reported within growing individuals were the difficulty in adjusting to and engaging the precision wings of the MA component, and a resulting open bite (either posterior or lateral). In non-growing individuals, poor predictability and efficacy of tooth movement were noted.

Conclusions/clinical implications: Clear aligner therapy may overcome common pitfalls during Class II correction as it provides solid incisor and vertical control during therapeutic management. However, the poor predictability of tooth movement as well as a reliance on compliance may limit aligner utilisation. Further research into the predictability of CAT for the treatment of Class II malocclusions in growing populations is indicated.

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Introduction

An ideal occlusion, as defined by Edward Angle, relates the mesiobuccal cusp of the upper first permanent molar occluding with the mesiobuccal groove of the lower first permanent molar.¹ Class II malocclusions are diagnosed when the upper molar mesiobuccal cusp lies mesial, or anteriorly, to the lower molar mesiobuccal groove. The global prevalence of Class II malocclusions is approximately 19.6% (range 2–63%)² and can be challenging to orthodontically correct.³ Using a range of available techniques and treatment modalities, treatment may depend upon the patient's age, the severity

of an associated skeletal dysplasia, and specific modifying factors. The techniques include (but are not limited to) two-phase treatments, surgical procedures, functional appliances, fixed appliances, and clear aligner therapy (CAT) with or without the combination of other auxiliaries and modalities.

From 1998, CAT has provided a treatment alternative to conventional fixed appliances.⁴ The use of CAT has increased in popularity over the last decade as several companies have developed their own appliances following the success of Invisalign (Align Technology, Santa Clara, CA, USA).^{5,6} In its simplest, earliest form, CAT was presented as a series of

thermoplastic retainers that would guide each tooth and arch into successive positions until the desired outcome was reached. However, this was initially limited to simpler cases, and severe malocclusions, crowding, and excessive spacing were treated using other orthodontic mechanisms. Extraction cases may be more challenging using CAT as torque control is less predictable and tooth tipping can occur.^{4,7,8} While fixed appliances may have been the traditional treatment choice, the addition of buttons, cutouts, changes in the thermoplastic material, along with other adjuncts such as Class II elastics, TADs, or combinations with other functional appliances, have increased the use of CAT in more complex cases.^{4,9,10}

Despite progress involving adjuncts and auxiliaries to broaden the scope of malocclusions suitable for CAT management, there is limited evidence for the use of CAT to correct Class II malocclusions. Therefore, this scoping review collated treatment approaches of CAT used for the correction of Class II malocclusions, including the effectiveness, applied approaches within a course of treatment, and the overall benefits and limitations of the modality.

Materials and methods

Scoping reviews permit a more comprehensive collection of data on a wider range of findings within a given topic. This proves to be particularly valuable in fields in which data is broad on a range of subtopics but may be insufficient for a systematic review.^{11–13} There is robust evidence on a range of subtopics within Class II correction and CAT respectively, but less so on Class II correction using CAT. Therefore, a scoping review was deemed the most appropriate for the present study. A search of PROSPERO, the Joanna Briggs Systematic Review register, PubMed and Scopus was completed and there were no other equivalent published nor commenced scoping reviews identified.

Identifying articles for inclusion

Six databases were searched in November 2023 using keywords and index terms related to “Class II Malocclusions” and “Clear Aligners”. In addition to peer-reviewed studies, a grey literature search was conducted using analogous keywords. No restrictions were placed on study design, nor country of origin; however, only papers in English were considered. The search strategy was first developed for PubMed and

Table I. Inclusion and exclusion criteria for full-text review

Inclusion	Exclusion
Class II malocclusions corrected by CAT	Audio and visual media sources
	Animal studies
	Participants with craniofacial abnormalities
	Do-it-yourself aligners systems
	CAT as an adjunct to Class II correction

CAT, clear aligner therapy.

then adapted according to the design required for EMBASE (Ovid), Web of Science, Scopus, ProQuest Central, and the DOSS (Dentistry and Oral Sciences Source) databases (Appendix I). The grey literature was searched including all global orthodontic website links (obtained through the Australian Society of Orthodontics website)¹⁴ (Appendix II) as well as clear aligner company websites¹⁵ using the search terms “Class II Malocclusions” and “Clear Aligners” (Appendix III).

Texts were uploaded to COVIDENCE (Veritas Health Innovation Ltd, Melbourne, Australia) following which duplicates were removed. Three independent reviewers (S.W.C.J, L.M.S, E.D.J) screened the titles and abstracts from the initial search of the databases and grey literature sites. Any relevant articles flagged during this process underwent a full-text review. The texts were screened using the inclusion and exclusion criteria (Table I). Inter-reviewer conflicts on a particular decision regarding inclusion/exclusion were resolved via discussion between the reviewers. For each conflict, a justification from each reviewer was required and discussed. This was independently reviewed by a third reviewer before a final decision.

Data extraction and synthesis

Data were extracted and organized into a piloted extraction form by the reviewers (L.M.S, S.W.C.J, E.D.J). Extracted data included the author’s names, the year of article publication, the geographical location of the study, the study aims and design, the population

characteristics, intervention(s), the techniques/modalities used, the use of overcorrection, the efficacy of treatment and its measurement, refinements required, and the benefits/limitations of the CAT/modality in the treatment of Class II malocclusions. If any additional trends were noted, a new search was conducted throughout all of the papers to determine if a concept/term was discussed within the study. Data were categorically synthesized and tabulated according to the growth status of included individuals (<18 years “growing,” and ≥ 18 years “non-growing”).

Results

The search identified a total of 2271 texts, from which 557 duplicates were removed (Figure 1). After unrelated/irrelevant papers were discarded during a title and abstract screening, 123 papers were identified for retrieval following which 46 papers were excluded based on the inclusion and exclusion criteria, resulting in 77 papers initially included for data collection. However, after a second detailed review against the inclusion and exclusion criteria, another 18 studies were excluded resulting in a final total of 59 papers (Figure 1). Thirty-seven of the studies were on growing individuals, 21 reported on non-growing individuals and one study included a mix of growing and non-growing individuals.

Results: growing populations

Location and age: Table II presents a summary of the characteristics of the 37 included studies of growing individuals. Countries of affiliation of the first author included the USA ($n=9$),^{18,20,23,26,29,35,36,50,51} Italy ($n=8$),^{22,24,31,39,41,44,45,48} Canada ($n=7$),^{16,28,32,42,43,47,49} China ($n=6$),^{17,25,27,37,46,52} Saudi Arabia ($n=2$),^{19,33} Germany ($n=1$),²¹ UAE ($n=1$),³⁰ Greece ($n=1$),³⁴ Slovakia ($n=1$),³⁸ Singapore ($n=1$).⁴⁰ A total of 482 individuals had a Class II malocclusion treated using CAT across all studies. The mean age of the treated patients was 14.1 years.

Duration and efficacy: the mean treatment duration was 18 months. There were seven studies that showed a treatment duration or allocated treatment time ≤12 months.^{20–22,30,35,41,47} There was a combination of skeletal, dental, unilateral and bilateral cases. Thirty-three of the 37 studies demonstrated the success/efficacy of CAT in treating Class II malocclusions: 10 retrospective cohort studies,^{16,19,22,25,26,31,38,45,46,49}

four prospective cohort studies,^{24,36,48,50} and 19 case reports^{17,18,20,21,23,29,32–35,37,39–44,47,52} showed success in reaching the treatment objectives and/or achieving a Class I molar relationship. However, one case report mentioned that success only occurred for “modest Class II correction”,³⁵ and one study still had a Class II canine relationship remaining on the right side after 28 months of treatment.²⁷

Techniques and adjuncts: broadly, there were three categories of CAT described as CAT alone, CAT plus mandibular advancement (MA; i.e. precision wings) and CAT plus arch distalization (sequential distalization of the upper dentition) (Table III). Any studies that mentioned Invisalign “First” or Invisalign “Teen” were considered to be part of the general CAT category as the principals of design and use were not uniquely different from techniques used within a general course of CAT. Within the CAT plus distalization reports, two texts specifically mentioned the “DF2 protocol”, which involved a short preliminary phase of sagittal correction followed by full arch CAT to correct any remaining malalignments.^{20,26} One text specifically mentioned that the DF2 protocol may be beneficial in cases which require significant Class II correction.²⁶ As this was not definitively stated, it was omitted from the table. Elastics were used in treatment by 21 studies^{16–18,20–22,24,26,32,34–38,41–44,47,49,52} (Table III). Mostly this was in the form of Class II elastics, but the use of vertical elastics³⁷ and Class III elastics was noted.³² Bite ramps were used in four studies in a CAT plus MA case^{37,42,43} and a CAT case alone.³⁵ Overcorrection was utilized in a number of reports^{17,23,43,44} and one study mentioned that it may be routinely required.²⁶ Additional aligners (mentioned as “refinement”) were required in 14 studies.^{17,20,21,23,24,29,32,33,35,37,40,44,48,52}

Comparison and conventional methods: of the 16 cohort studies, nine had specific comparison groups: one of non-treated individuals,¹⁹ one comparing a fixed bracket group,³⁸ one treated using the Herbst appliance,¹⁶ one with the pendulum appliance,²⁴ four with the twin block (TB),^{28,31,45,49} and one study compared CAT with a control, vanBeek appliance, Herbst appliance, and TB groups.⁴⁶ Compared to a control of non-treated individuals, one study found that CAT plus MA produced predominantly skeletal changes in favour of Class II correction.¹⁹ Compared to fixed appliances, CAT was found to produce a similar correction of sagittal discrepancies but with

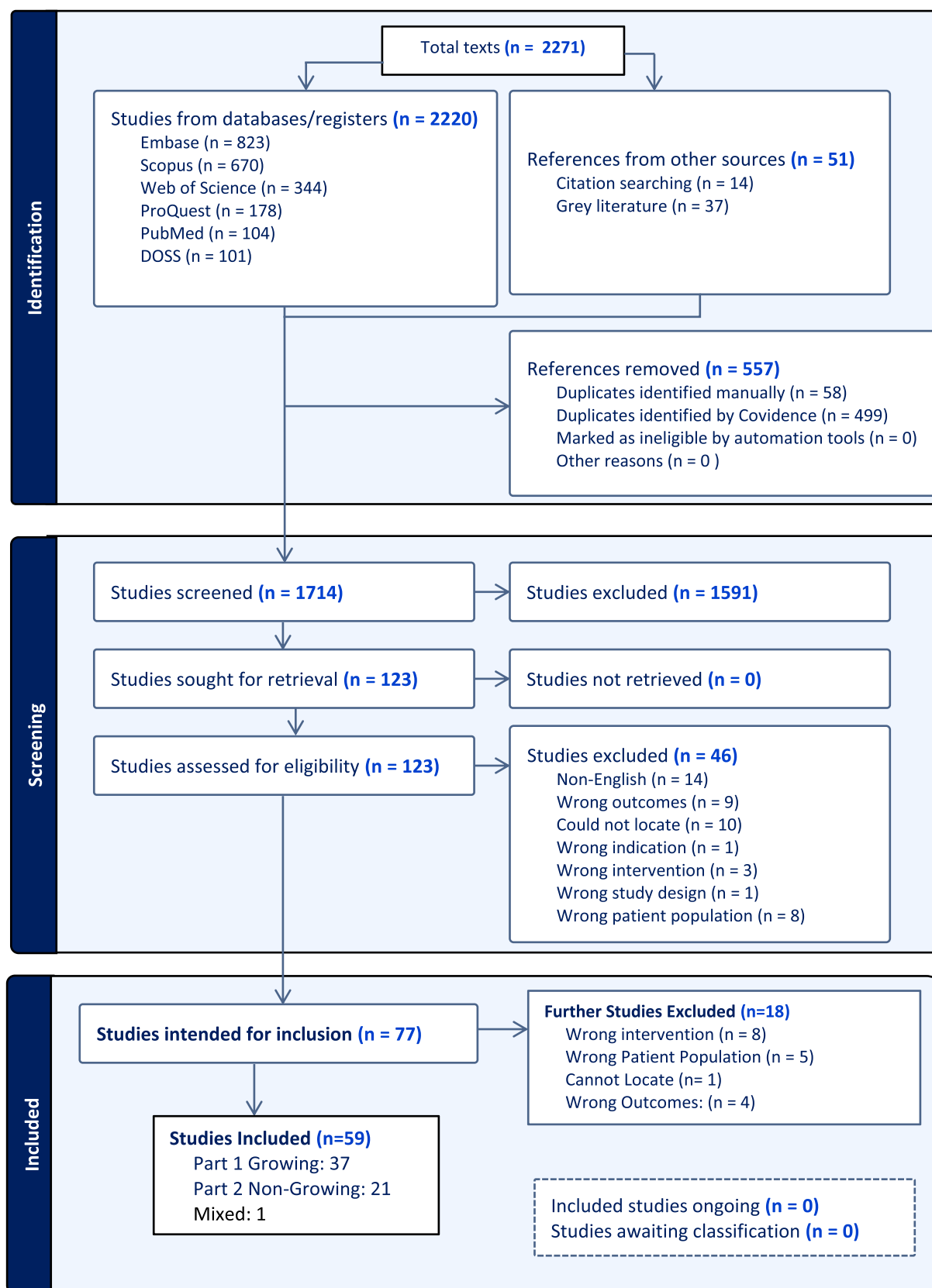


Figure 1. PRISMA flow diagram.

Table II. Characteristics of the included 37 studies in the growing population

Authors	Aim/purpose	Study design	Number of individuals in CAT group (n)	Number of individuals (n) in control/ comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
1 Hosseini, 2023 ¹⁶	To compare the skeletal and dental changes of patients with a Class II relationship treated with clear aligner mandibular advancement (MA) and Herbst appliances followed by comprehensive orthodontic treatment.	Cohort (Retrospective)	20	Total = 40 Herbst = 20	13.1	CAT + MA	Good Md incisor control Good vertical control Effective skeletal or MA changes	
2 Sun, 2023 ¹⁷	This case report presents successful combined orthopedic and orthodontic treatment using clear aligners with MA features in a growing patient with Class II, Division 1 malocclusion characterized by mandibular retrusion and mandibular incisor protrusion.	Case Report	1	N/A	14.75	CAT + MA	Good Md incisor control Good vertical control Effective skeletal or MA changes Comfort Aesthetics Simultaneous movements	Temporary posterior or lateral open bite
3 Glaser, 2015 ¹⁸	NA – “Based on this logic, I developed the following protocol to treat growing Class II teen patients simultaneously with Invisalign Teen® and Class II elastics”	Case Report	3	N/A	16, 13, 14	CAT (Invisalign* Teen)	Good Md incisor control Good Md plane angle control Hygiene Simple/ neat	
4 Al Subaie, 2023 ¹⁹	This study evaluated the dento-skeletal and soft tissue changes for Class II malocclusion patients treated with Invisalign clear aligners with mandibular wings (IAMV)	Cohort (Retrospective)	50	Total = 70 Control = 20	12	CAT + MA	Effective skeletal or MA changes Aesthetics	

Table II. Continued

Authors	Aim/purpose	Study design	Number of individuals in CAT group (n)	Number of individuals (n) in control/ comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
5 Ferris, 2022 ²⁰	This article details a new Invisalign treatment protocol referred to as DF2	Case Report	1	N/A	14	CAT (Distalization; DF2)	Good incisor control Good vertical control Aesthetics Good 3D control Simultaneous movements	
6 Schupp, 2010 ²¹	Describes treatment of a unilateral Class II malocclusion with Invisalign and elastics, as well as a second Class II case treated with the Carrière Distalizer** followed by Invisalign appliances	Case Report	2	N/A	14	CAT (Distalization)	Comfort Aesthetics	
7 Cremonini, 2022 ²²	To analyze the skeletal and dentoalveolar effects of a new clear functional appliance in a sample of patients close to growth spurt with class II malocclusion attributable to mandibular retrusion	Cohort (Retrospective)	15		10.3	CAT + MA (F22** Young Appliances)	Effective skeletal or MA changes Comfort Aesthetics -	
8 Gurgel, 2023 ²³	To present the 3-dimensional (3D) effects of clear aligner MA therapy in two growing patients with a Class II relation- ship	Case Report	2	N/A	12.3, 11.8	CAT + MA	Good Mx incisor control Good vertical control Effective skeletal or MA changes Comfort Aesthetics Simultaneous movements	Difficulty engaging precision wings Temporary posterior or lateral open bite
9 Lione, 2022 ²⁴	To compare the effects on vertical dentoalveolar dimension produced by Pendulum appliance and Clear Aligners in patients with Class II malocclusion	Cohort (Prospective)	20	Total = 40 Pendulum group = 20	17.2	CAT (Distalization)	Good vertical control	

10	Kong, 2023 ²⁵	To investigate the clinical effect of Invisalign MA on the treatment of mandibular retraction in adolescents	Cohort (Retrospective)	30	Nil/N/A	11.6	CAT + MA	Effective skeletal or MA changes
11	Otis, 2021 ²⁶	Evaluated the treatment effectiveness and efficiency of the DF2 protocol for correction of class II malocclusions in comparison to conventional protocol using Invisalign	Cohort (Retrospective)	22	Nil/NA	15.3	CAT (Disalization; DF2)	Good Md incisor control Aesthetics
12	Liu, 2022 ²⁷	The current study described an 11-year-old female patient with Angle's Class II relationship and skeletal Class II base relationship with retrognathic mandible and orthognathic maxilla	Case Report	1	N/A	11	CAT + MA	Good vertical control Comfort Simple
13	Zybutz, 2021 ²⁸	To compare patients' experiences with the Invisalign Teen with Mandibular Advancement (ITMA) and Twin Block (TB) appliances, both initially and after several months of wear.	Cohort (Qualit/ Survey)	45	Total = 68 TB = 23	13.6	CAT (Invisalign Teen)	Less noticeable and easier to insert than TB (i.e. and aesthetics) Simplicity - easier to insert than TB Discomfort: greater tooth pain compared to TB
14	Fischer, 2010 ²⁹	As this article shows, however, there are other successful ways to treat Class II cases using the Invisalign system without auxiliaries.	Case Report	3	N/A	13, 15, 14	CAT (Disalization)	Simultaneous movements
15	Sabouni, 2022 ³⁰	To examine the skeletal, dental, and soft-tissue cephalometric effects of class II correction using Invisalign's mandibular advancement feature in growing patients.	Cohort (Retrospective)	32	Nil/NA	13	CAT + MA	Good Md incisor control Effective skeletal or MA changes

Table II. Continued

	Authors	Aim/purpose	Study design	Number of individuals in CAT group (n)	Number of individuals (n) in control/comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
16	Caruso, 2021 ³¹	The current study aimed to analyse the dentoskeletal effects of the Invisalign mandibular advancement (MA) device in the treatment of skeletal Class II malocclusions.	Cohort (Retrospective)	10	Total = 20 TB = 20	10	CAT + MA	Good Mx incisor control Effective skeletal or MA changes	
17	Robertson, 2022 ³²	To present a unique case report that was treated with a new perspective in maximizing skeletal improvement in a late adolescent male with skeletal Class II malocclusion and deep overbite. This case report aims evaluate if upper anterior teeth proclination with posterior intrusion using clear aligners can improve skeletal and dental Class II malocclusion with deep overbite in a late adolescent male.	Case Report	1	N/A	15	CAT	Effective skeletal or MA changes Aesthetics	
18	T. Eshky, 2022 ³³	This case report describes an orthodontic treatment using clear aligners in a patient with Class II malocclusion associated with a deep bite.	Case Report	1	N/A	16	CAT + MA	Effective skeletal or MA changes Comfort Aesthetics Hygiene	Temporary posterior or lateral open bite
19	Koukou, 2022 ³⁴	This case report describes the orthodontic management of a 12-year-old male patient having skeletal Class II malocclusion due to mandibular retrognathia.	Case Report	1	N/A	12	CAT + MA	Good Md incisor control Effective skeletal or MA changes	Temporary posterior or lateral open bite

20	Gorton, 2022 ³⁵	The present article describes the use of Invisalign First* for Phase I treatment of young patients with Class II, division 2 malocclusions.	Case Report	1	N/A	10	CAT (Invisalign* First)	Simultaneous movements	
21	Glaser, 2022 ³⁶	A prospective, multicenter clinical study was conducted to test the safety and effectiveness of this appliance in growing patients with Class II malocclusions. Interim results from the study are reported here.	Cohort (Prospective)	60	Nil/NA	12.75	CAT + MA	Good Md incisor control Good vertical control Comfort Simultaneous movements Molar extrusion control	Difficulty engaging precision wings Discomfort (minor)
22	Xie, 2023 ³⁷	This case report illustrates a nonsurgical and nonextraction approach with A6 clear aligners for treating low-angle skeletal Class II deep bite malocclusion in a growing patient.	Case Report	1	N/A	12	CAT + MA	Effective skeletal or MA changes Comfort Aesthetics	Poor efficacy/ predictability of tooth movement
23	Dianiskova, 2021 ³⁸	To compare the dental and skeletal effects of intermaxillary elastics on the correction of mild Angle's Class II division 1 malocclusion with clear aligner treatment (CA) versus fixed multibracket (FMB) in growing patients.	Cohort (Retrospective)	24	Total = 49 Fixed brackets = 25	12.7	CAT	Good Md incisor control	
24	Pavoni, 2022 ³⁹	No published studies have evaluated the effect of MA aligners on skeletal Class II treatment during the pubertal growth peak. This article reports the outcome of such treatment.	Case Report	1	N/A	12	CAT + MA	Effective skeletal or MA changes Simultaneous movements	
25	Hoa, 2021 ⁴⁰	This case report details the successful treatment of a 14-year-old female patient with Class II malocclusion, crowding, and dental crossbite using extraction and the Invisalign® system.	Case Report	1	N/A	14	CAT (Distalization)	Aesthetics Good control of root axes	Temporary posterior or lateral open bite

Table II. Continued

	Authors	Aim/purpose	Study design	Number of individuals in CAT group (n)	Number of individuals in control/comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
26	Siaderini, 2022 ⁴¹	The aim of this case report is to outline the clinical management of the occlusal plane of a growing Class II division 1 deep bite patient treated with aligners and Class II elastics.	Case Report	1	N/A	12.7	CAT (Invisalign Teen)	Good vertical control Effective skeletal or MA changes	
27	Iwasjuk, 2021 ⁴²	Treatment Goals: 1. Correct the bite to Class I molar and canine without extractions. 2. Reduce the incisor proclination. 3. Close all the spaces. 4. Correct the deep bite. 5. Maintain good oral hygiene during and after orthodontic treatment	Case Report	1	N/A	11.7	CAT + MA	Simultaneous movements	Temporary posterior or lateral open bite
28	Iwasjuk ⁴³	Treatment goals Bring the permanent upper canines into the arch and align all the teeth Correct the bite to Class I molar and canine without extractions. Reduce the deep bite. Widen the arches and broaden the smile. Maintain good oral hygiene during and after orthodontic treatment.	Case Report	1	N/A	13.1	CAT + MA		Difficultly engaging precision wings

29	Giancotti, 2017 ⁴⁴	The aim of this work is to show how it is possible to treat Class II malocclusions by means of aligners according to suggested treatment protocols herein.	Case Report	2	N/A	13, 12	CAT	Good vertical control Comfort Aesthetics Simple – ease of process
30	Lombardo, 2022 ⁴⁵	The aim of this study was to compare the changes produced by the TB versus those by MA.	Cohort (Retrospective)	21	Total = 56 TB = 35	11, 1	CAT + MA	Good incisor control Good vertical control Simultaneous movements
31	Wu, 2023 ⁴⁶	Therefore, this retrospective study aimed to deeply compare the skeletal and dentoalveolar effects of MA, Vanbeek Activator, Herbst and Twin-Block in children with Skeletal Class II Malocclusion.	Cohort (Retrospective)	14	Total = 63 Control = 12 van Beek Activator = 14 Herbst Appliance = 11 TB = 12	12, 1	CAT + MA	Good Md incisor control Effective skeletal or MA changes Comfort Aesthetics Increased accuracy Simultaneous movements
32	ElBialy, 2019 ⁴⁷	The traditional technique involves the use of cervical headgear to extrude the maxillary molars and restrain maxillary growth while allowing forward arcial growth of the mandible. This case report utilises the same philosophy but using clear aligners. A 12-year-old girl presented with a skeletal Class II relationship due to mandibular retrognathism. This patient also presented with full-step Class II division 1 malocclusion with an increased overjet and deep overbite in addition to a spaced mandibular arch.	Case Report	1	N/A	12	CAT (Distalization)	Good Md incisor control

Table II. Continued

	Authors	Aim/purpose	Study design	Number of individuals in CAT group (n)	Number of individuals (n) in control/comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
33	Balboni, 2023 ⁴⁸	The aim of the present prospective study was to detect the effects on vertical dentoskeletal dimension produced by molar distalization with clear aligners in a group of subjects with class II malocclusion.	Cohort (Prospective)	20	Nil/N/A	17.2	CAT (Distalization)	Good vertical control	
34	Blackham, 2020 ⁴⁹	The purpose of this retrospective cephalometric study was To compare short-term skeletal, dental, and soft tissue effects in Class II malocclusions treated with Invisalign® with Mandibular Advancement Feature (IMAF) as compared to Twin Block (TB) appliance, and age and gender matched historical controls.	Cohort (Retrospective)	32	Total = 64 TB = 32		CAT + MA	Good Md incisor control Good vertical control Aesthetics	

35	Ravera, 2021 ⁵⁰	To evaluate the dentoskeletal effects of the Invisalign® Mandibular Advancement (MA) (Align Technology, San José, CA, USA) feature in skeletal Class II growing patients with mandibular retrusion, at pre-pubertal and pubertal stages	Cohort (Prospective)	40	8 – 15	CAT + MA	Effective skeletal or MA changes Aesthetics Comfort
36	Align Technology, 2017 ⁵¹	NA	N/A - Online "Announcement"	N/A	"Teens"	CAT (Invisalign Teen)	Comfort Hygiene Simple/ efficient Simultaneous movements
37	Sun, 2022 ⁵²	This case report describes the orthodontic and orthopedic treatment of a Class II Division 2 adolescent with mandibular retrognathism and excessive overbite using Invisalign aligners with mandibular advancement precision wing features.	Case Report	1	12	CAT + MA	Good incisor control Comfort Simultaneous movements

CAT, clear aligner therapy; DF2, two-phased clear aligner protocol; MA, mandibular advancement; Md, mandibular; Mx, maxillary; TB, twin block.

*Invisalign (Align Technology, San Jose, CA, USA).

**F22 (Sweden and Martina, Due Carrare (PD), Italy).

Table III. Conceptual model distribution of 26 studies that included auxiliary or adjunct therapies in growing populations

Authors	Elastics	Bite ramps	Overcorrection	Additional aligners
Hosseini, 2023 ¹⁶				
Sun, 2023 ¹⁷				
Glaser, 2015 ¹⁸				
Ferris, 2022 ²⁰				
Schupp, 2010 ²¹				
Cremonini, 2022 ²²				
Gurgel, 2023 ²³				
Lione, 2022 ²⁴				
Otis, 2021 ²⁶				
Fischer, 2010 ²⁹				
Robertson, 2022 ³²				
T. Eshky, 2022 ³³				
Koukou, 2022 ³⁴				
Gorton, 2022 ³⁵				
Glaser, 2022 ³⁶				
Xie, 2023 ³⁷				
Dianiskova, 2022 ³⁸				
Hoa, 2021 ⁴⁰				
Staderini, 2022 ⁴¹				
Iwasiuk, 2021 ⁴²				
Iwasiuk ⁴³				
Giancotti, 2017 ⁴⁴				
El-Bialy, 2019 ⁴⁷				
Balboni, 2023 ⁴⁸				
Blackham, 2020 ⁴⁹				
Sun, 2022 ⁵²				

Highlighted boxes show a positive response to the type of treatment modality.

better control of the lower incisors.³⁸ CAT and Herbst appliance cases were found to produce similar results with CAT having better vertical and lower incisor control.¹⁶ Compared with the pendulum appliance, CAT was found to have less clockwise mandibular rotation (pendulum +2.8 degrees versus CAT -4.2 degrees) and a better ability to control the vertical dimension.²⁴ Compared to the TB appliance, three studies found comparable results between CAT and the TB; however of these, one found CAT to have better control of the upper anterior teeth,³¹ one found CAT to have better control of the lower incisors,⁴⁹ and one study found the TB encouraged greater forward

growth of the soft tissue chin.⁴⁵ One qualitative study and survey found that individuals reported CAT plus MA as less intimidating, less noticeable and easier to insert; however, it was also associated with more tooth pain, and soft tissue soreness.²⁸ Compared to control, vanBeek and Herbst appliance cases, CAT was found to have solid control of the lower incisors although the vanBeek appliance was found to have the greatest skeletal effect.⁴⁶

Benefits and limitations: overall, the common benefits reported, which also pertained to CAT in general, included the advantage of aesthetics,^{17,19-23,26,32,33,37,40,44,46,49,50}

comfort,^{17,21–23,27,33,36,37,44,46,50–52} improved patient hygiene^{18,33,51} and the ease/simplicity of use of the appliance and/or the process.^{18,27,28,44,51} Regarding aesthetics, one study mentioned that CAT was less noticeable than the TB appliance.²⁸

Twelve studies reported the benefit that enabled CAT to perform simultaneous or multiple movements of teeth and/or in conjunction with MA.^{17,20,23,29,35,36,39,42,45,46,51,52}

Common benefits that pertain more specifically to Class II correction using CAT reported good/beneficial control of the mandibular incisors,^{16–18,26,30,34,36,38,46,47,49} good/beneficial control of the maxillary incisors,^{23,31} general good/beneficial control of the incisors^{20,45,52} and good/beneficial vertical control.^{16,17,20,23,24,27,36,41,44,45,48,49} An additional common noted benefit was the effective advancement of the mandible and/or beneficial skeletal changes.^{16,17,19,22,23,25,30–34,37,39,41} One paper reported successful skeletal changes but only when treatment by CAT plus MA occurred during the pubertal growth spurt.⁵⁰ It should be noted that one study reported vertical control in relation to the premolars rather than vertical dimension control, and control of the incisors from a general three-dimensional control of the dentition.²⁰ Lesser reported benefits included good mandibular plane angle control,¹⁸ 3D control,²⁰ molar extrusion control,³⁶ root axis control,⁴⁰ and increased accuracy.⁴⁶

Common appliance limitations included difficulty in engaging or adjusting the precision wings in CAT plus MA treatment,^{23,36,43} and a resulting temporary posterior/lateral open bite during treatment.^{17,23,24,33,34,40,42} One study discussed the poor predictability of tooth movement.³⁷ An additional study that compared the TB appliance and CAT plus MA treatment noted that individuals undergoing CAT plus MA found it less noticeable and easier to insert than the TB; however, greater tooth discomfort was experienced compared to the TB group.²⁸ Similarly, an additional study also mentioned discomfort/pain although clarified that it was minor and not consistent, as patients stated “sometimes” or “never” in regard to their discomfort.³⁶

The concept of compliance was mentioned in 22 studies.^{17–20,22–24,26,28,29,32,33,36,38–41,44,45,48,50,52} Of these, compliance was acknowledged either as a general comment of CAT’s reliance on patient co-operation for success, specifically making compliance an inclusion criterion of their study,

and/or acknowledging the compliance of the individual(s) within the study. One study mentioned no issue related to compliance,⁵¹ although it was a promotional communication, while one study found no differences in compliance between CAT and the TB groups.⁴⁹ An additional study further stated that the discreteness and comfort of CAT may promote compliance over other removable appliances such as the TB.⁴⁶

Results: non-growing populations

Location and age: a total of 21 studies discussed CAT for Class II correction in non-growing individuals (Table IV). Countries of affiliation of the first author included USA ($n=7$),^{53,54,58,63,69,70,73} Italy ($n=4$),^{59,60,66,67} Brazil ($n=2$),^{61,68} China ($n=2$),^{56,65} India ($n=2$),^{55,71} Australia ($n=1$),⁵⁷ Bolivia ($n=1$),⁶² Canada ($n=1$),⁶⁴ and Taiwan ($n=1$).⁷² The mean age of non-growing patients was 25.9 years.

Duration and efficacy: the mean treatment time for non-growing patients was 18.8 months. Several studies reported a treatment time of ≤ 12 months.^{55,58,60,64,68} Of the five relevant articles, three described cases that were unilateral Class II molar in nature,^{55,60,68} one reported a bilateral half-unit (end-to-end molar) Class II case,⁶⁴ and one article described cases of mixed/non-specific Class II severities, and whose treatment time was standardised.⁵⁸ Of the 21 studies, the efficacy of CAT in Class II correction/treatment objective(s) was achieved in 17 studies (i.e. success in Class II correction and or mention of CAT ability to correct Class II malocclusions).^{53–57,59,60,62–69,71,72}

Techniques and adjuncts: treatment approaches included both extraction^{53,62} and non-extraction plans^{54,57,59–61,63,65,66,68,69,71–73} in addition to CAT alone, CAT plus arch distalisation, CAT plus MA and CAT plus temporary anchorage devices (TADs). One study included extraction and non-extraction cases.⁵⁸ Class II elastics were prescribed in 15 studies^{53,54,57–63,65,66,68,69,72,73} (Table V). Typically, the elastics were placed from the upper canine tooth to the lower first molar and attached to the clear aligners by a variety of mechanisms. Where specified, the elastic attachments included TADs, hooks, buttons, or a combination (Table V). Overcorrection was mentioned in five texts.^{57,62–64,70} Additional aligners (refinement) were mentioned in

Table IV. Characteristics of the 21 included studies of the non-growing population

Authors	Aim/purpose	Study design	Number of Class II individuals in CAT group (n)	Number of individuals (n) in control/comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
1 Chang, 2019 ⁵³	To report on a surgery-first approach to skeletal class II correction followed by Invisalign treatment.	Case Report	1	N/A	20	Surgery (Ieforte II) CAT + TADs		
2 Klein, 2013 ⁵⁴	The aim of this retrospective study was to examine the skeletal and dental effects of nonextraction Class II treatment in the adult dentition with the Invisalign system and interact elastics	Cohort (Retrospective)	28	Nil	35.5	CAT	Good vertical control Reliable upper molar distalization Aesthetics	

3	Dhanasekaran, 2021 ⁵⁵	The objective of this report was to explain an advanced orthodontic treatment for correction of Angle's class II subdivision malocclusion with proclined upper and lower incisors, increased overjet, midline spacing in upper & lower anteriors and upper midline deviation towards the left side by 3 mm relating to the facial midline using clear aligners	Case Report	1	N/A	19	CAT	Good vertical control Aesthetics Hygiene
4	Chen, 2023 ⁵⁶	To investigate the clinical changes of maxillary central incisor and alveolar bone in Class II Division 2 nonextraction treatment with fixed appliances or clear aligners on the basis of cone-beam computed tomography	Cohort (Retrospective)	18	Total = 59 Conventional bracket = 20 Selfligating bracket = 21	22.67	CAT	

Table IV. Continued

Authors	Aim/purpose	Study design	Number of Class II individuals in CAT group (n)	Number of individuals (n) in control/comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
5 Vlaskalic, 2018 ⁵⁷	Two default staging protocols are currently available to Invisalign system users for correcting Class II canine and molar relationships: "distalization," referring to tooth-by-tooth sequential distal movement to the prescribed degree, or "elastic simulation," representing clinical Class II elastic wear as a differential anteroposterior "jump" of the virtual arches.... Indications and management of both are described in this article	Case Report	2	N/A	23	CAT (Sequential Distalization) CAT (Md jump)	Aesthetics Simultaneous movements Predictable/simplicity	

6	Patterson, 2021 ⁵⁸	This research aimed to determine whether Class II malocclusion can be treated with clear aligners after completing treatment with the initial set of aligners (i.e. without refinement phase)	Cohort (Retrospective)	40	Total = 80 Class I with CAT = 40	35.25	CAT (Sequential Distalization)	Poor efficacy/predictability of tooth movement Temporary posterior open bite Too many simultaneous movements
7	Rongo, 2022 ⁵⁹	To evaluate the dental effects of the treatment with clear aligners and intermaxillary elastics in adult patients with Class II malocclusion.	Cohort (Retrospective)	20	Nil	27.9	CAT	Good/beneficial incisor control Good extrusion control
8	Lombardo, 2018 ⁶⁰	To describe an esthetic orthodontic treatment using aligners in an adult patient with class II subdivision associated with crowding and dental crossbite	Case Report	1	N/A	18	CAT	Good/beneficial incisor control Good vertical control Aesthetics Comfort Hygiene

Table IV. Continued

Authors	Aim/purpose	Study design	Number of Class II individuals in CAT group (n)	Number of individuals (n) in control/ comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
9 Taffarel, 2022 ⁶¹	This retrospective study aimed to evaluate whether the treatment of Class II malocclusion with Invisalign aligners with sequential distalization of posterior teeth in adult patients would meet the criteria of the American Board of Orthodontics (ABO) standards for the treatment and assess the predictive value of ClinCheck Pro software with the final results comparing the initial time, predictive planning using ClinCheck Pro software, and the final time without any require refinement.	Cohort (Retrospective)	32	Nil	35.47	CAT (Sequential Distalization)		Poor efficacy/ predictability of tooth movement Too many simultaneous movements

10	Antelo, 2021 ⁶²	This case report illustrates the treatment of a Class II, division 2 malocclusion and deep over-bite in an adult patient using maxillary first-premolar extractions, clear aligners, TADs, and Class II elastics	Case Report	1	N/A	19	CAT + TADs	Aesthetics Comfort Hygiene Ease
11	Gudhimella, 2021 ⁶³	This case report illustrates a non-extraction, non-surgical orthodontic treatment of 5 mm anterior open bite in a non-growing adult patient, utilizing clear aligner therapy.	Case Report	1	N/A	26	CAT	Aesthetics Molar intrusion advantage Simultaneous movements
12	El-Bialy, 2021 ⁶⁴	The use of PBM to accelerate treatment has previously been reported with different Invisalign protocols, but the present article is the first to describe the combination of PBM with the MA feature in adults.	Case Report	1	N/A	31	CAT + MA (with Photo-biomodulation Device)	

Table IV. Continued

Authors	Aim/purpose	Study design	Number of Class II individuals in CAT group (n)	Number of individuals (n) in control/comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
13 Li, 2023 ⁶⁵	This study aimed to investigate the efficacy of molar distalization with or without anterior teeth retraction.	Cohort (Retrospective)	43	Nil/N/A	28.15	CAT (Sequential Distalization)	Aesthetics Comfort Convenience	Poor efficacy/ predictability of tooth movement
14 Ravera, 2016 ⁶⁶	The aim of the present study was to test the hypothesis that bodily maxillary molar distalization was not achievable in aligner orthodontics.	Cohort (Retrospective)	20	Nil	29.73	CAT (Sequential Distalization)	Good/beneficial incisor control Able to distalize molars without significant tipping/ vertical movements of the crown	
15 D'Antò, 2023 ⁶⁷	Therefore, the objective of this study is to evaluate the predictability of maxillary molar distalization and derotation using clear aligners.	Cohort (Prospective)	16	Nil	25.7	CAT (Sequential Distalization)	Aesthetics	Poor efficacy/ predictability of tooth movement
16 Shimizu, 2021 ⁶⁸	The aim of this research was to address the planning and treatment of a Class II/2 malocclusion treated without extractions, using orthodontic clear aligners.	Case Report	1	N/A	20	CAT (Sequential Distalization)	Good/beneficial incisor control Aesthetics Hygiene	

17	Bajaj, 2020 ⁶⁹	The aim of this study is to evaluate the pretreatment and posttreatment dentoskeletal effects of non growing individuals with dental Class II malocclusion treated with either clear aligners or fixed appliances, both using Class II elastics.	Cohort (Retrospective)	37	Total = 65 Fixed appliances = 28	33.9	CAT	Good/beneficial incisor control Good vertical control Aesthetics Hygiene	
18	Leavitt, 2019 ⁷⁰	This study aims to determine if Invisalign® produces sufficient treatment outcomes for Class II malocclusions, comparative to Class I malocclusions	Cohort (Retrospective)	22	Total = 43 Class I with CAT = 21	35.64	CAT	Aesthetics	Poor efficacy/ predictability of tooth movement
19	Harsha, 2023 ⁷¹	The objective of this systematic review was to systematically search the literature and assess the available evidence regarding the effectiveness of clear aligners in bringing about molar distalization with or without attachments	Systematic review	NA	N/A	18+	CAT (Sequential Distalization)	Good/beneficial incisor control Good vertical control Good control of mesio-distal tipping Efficacy of distalization	

Table IV. Continued

Authors	Aim/purpose	Study design	Number of Class II individuals in CAT group (n)	Number of individuals (n) in control/comparison groups	Age of individuals in CAT group (years)	Treatment approach	Benefits	Limitations
20 Lin, 2023 ⁷²	The treatment effects of Invisalign [®] are still obscure due to methodological limitations of previous studies. We introduced a method to comprehensively evaluate the dental and skeletal changes of Class II malocclusion treated non-extraction with Invisalign [®] and compare with the virtual simulation of ClinCheck [®] using digital models integrated into maxillofacial cone-beam computed tomography (CBCT).	Cohort (Retrospective)	7	Nil	7	CAT (Sequential Distalization)		Poor efficacy/predictability of tooth movement

21	Daher ⁷³	Dr. Sam Daher shares his current protocol for Class II correction with Invisalign and elastics.	Opinion piece	NA	N/A	NA	CAT (Sequential Distalization)
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CAT, clear aligner therapy; MA, mandibular advancement; TAD, temporary anchorage device.

Table V. Conceptual model distribution of 16 studies that included auxiliary or adjunct therapies in non-growing populations

Authors	Extraction case	Non-extraction case	Elastics	TADs	Hooks	Buttons
Chang, 2019 ⁵³						
Klein, 2013 ⁵⁴						
Vlaskalic, 2018 ⁵⁷						
Patterson, 2021 ⁵⁸						
Rongo, 2022 ⁵⁹						
Lombardo, 2018 ⁶⁰						
Taffarel, 2022 ⁶¹						
Antelo, 2021 ⁶²						
Gudhimella, 2021 ⁶³						
Li, 2023 ⁶⁵						
Ravera, 2016 ⁶⁶						
Shimizu, 2021 ⁶⁸						
Bajaj, 2020 ⁶⁹						
Harsha, 2023 ⁷¹						
Lin, 2023 ⁷²						
Daher ⁷³						

Highlighted boxes show a positive response to the type of treatment modality.

10 studies.^{53,56–58,62–64,66,70,72} Two additional studies mentioned that refinements would be required in their cases.^{61,67}

Comparison and conventional methods: of the 11 cohort studies within the non-growing population articles, four had comparison groups: two studies compared CAT in Class I versus Class II cases^{58,70} and two studies compared CAT with fixed appliance cases.^{56,69}

Benefits and limitations: the reported common benefits which relate to general CAT, include comfort,^{60,62,65} aesthetics,^{54,55,57,60,62,63,65,67–70} and improved oral hygiene.^{55,60,62,68,69} Common highlighted benefits which specifically pertained to Class II correction by CAT included good/beneficial control of the incisors (either mandibular/maxillary)^{59,60,66,68,69,71} and good/beneficial vertical control.^{54,55,60,69,71,72} Three studies also discussed the simplicity, ease or convenience of the appliance and/or treatment planning or process.^{57,62,65} Less common benefits were in relation to the efficacy of distalisation; one study concluded that CAT was able to provide reliable upper molar distalisation.⁵⁴ A recent systematic review determined that arch

distalisation using CAT was the most effective movement when compared to all other tooth movement mechanics.⁷¹ The study also mentioned the benefit of good control over mesio-distal tipping.⁷¹ An additional study indicated that CAT was able to distalise molars without significant tipping of their crowns.⁶⁶ Additional minor benefits mentioned were in relation to extrusion control,⁵⁹ advantageous molar intrusion,⁶³ and the benefit of implementing simultaneous tooth movements.^{57,63} Two papers mentioned that there may be too many simultaneous tooth movements which may be a disadvantage.^{58,61} One study mentioned that using CAT for Class II correction may lead to a reduced occurrence of root resorption and bone fenestration, but was not included in the table as the concept was theoretical and not conclusive as the study only stated that it “could reduce” root resorption/fenestration).⁵⁶ Common treatment limitations included poor efficacy or less than ideal predictability of tooth movement.^{58,61,65,67,70,72} Five of the studies were in relation to sequential distalisation.^{58,61,65,67,72} Three studies mentioned poor predictability/efficacy of tooth movement following a comparison of pre-treatment and either predicted or post-treatment

results by the American Board of Orthodontics Objective Grading System (ABO OGS),^{58,61,70} and three studies discussed a discrepancy between the predicted and the actual outcome.^{65,67,72} One study stated the possible need for further refinements due to a posterior open bite created during treatment.⁵⁸

In non-growing populations, the issue of “compliance” was acknowledged in 11 studies.^{53,54,56–59,65–67,69,70} The studies mentioned compliance as an explicit disadvantage of CAT and/or were mentioned as part of their inclusion or exclusion criteria (i.e. “good compliance” as part of their inclusion criteria). Two studies specifically mentioned that their cases had good compliance throughout CAT,^{62,63} while one study specifically mentioned poor compliance.⁵³

Discussion

The findings of the present study emphasise and corroborate the commonly known advantages of CAT noted as aesthetics, comfort, improved patient oral hygiene and ease of insertion and use.

Sequential distalisation (a staged distal movement of the posterior teeth to create space for anterior retraction) was commonly mentioned across the studies. This may increase treatment time, particularly when correcting full-unit Class II malocclusions due to the limit of movement per aligner.⁵⁷ A suggested approach to decrease treatment time was anterior correction programmed simultaneously and moving multiple teeth posteriorly instead of a single-tooth.⁵⁷ An alternate suggestion was a single “jump” whereby simultaneous programming of arch levelling and alignment occurs from stage one, with the occlusal relationship correction simulated by a single jump (either at the start, middle, or at the end of the ClinCheck staging).⁵⁷ However, it was considered that this approach was more anchorage-dependent and may place a larger reliance on elastic force and wear, making careful monitoring necessary to differentiate between true arch movement and perceived correction from anterior posturing of the mandible.

Class II elastics were used across both growing and non-growing patients and attached either to the clear aligners through hooks, bonded buttons or TADs (Figure 3). A hook refers to a notch cut out within the clear aligner (usually near the upper canines), while bonded buttons are composite resin or metal

attachments bonded to the tooth surface and which require adjustment of the aligner to compensate for the space created by the attachment. As operator preference may have a role to play in the selection of the elastic attachment, each approach carries benefits and limitations. Hooks may dislodge the clear aligner, while buttons may extrude the tooth as a result of the elastic force.^{57,73} Hooks may be beneficial when prosthetic crowns or large restorations prevent effective bonding, while buttons may be beneficial in cases in which extrusion of a particular tooth is warranted, or when appliance dislodgement is a concern.⁵⁷ One study suggested that hooks on the upper canines and buttons on the lower molars may be used to avoid a “mesial out rotation” of the upper canines if the buttons are not placed precisely along the canine’s long axis.⁷³ Temporary anchorage devices were used with elastics to counteract surgical relapse and to assist in anchorage during deep-bite correction.^{53,62}

The ability of CAT to perform multiple simultaneous tooth movements proves to be a benefit. This was particularly noted in the review of growing patients in which 12 studies reported the ability of CAT to simultaneously perform multiple movements of teeth and/or in conjunction with MA.^{17,20,23,29,35,36,39,42,45,46,51,52} This may reduce treatment time if alignment is carried out simultaneously along with MA. However, interestingly, in non-growing patients, it was noted that too many simultaneous tooth movements may be a drawback as two studies mentioned the disadvantage that excessive simultaneous movements may compromise treatment progress or outcomes.^{58,61}

As with the wear of any removable appliance, the heavy reliance on patient compliance under CAT cannot be ignored. Within the growing and non-growing populations, the majority of studies mentioned compliance as a contributing factor to treatment success. Compliance indicators are a simple, yet effective adjunct to monitor patient use, by placing a small dot at the posterior segment of a given tray; this small dot was comprised of a food dye (Erioglaucine disodium salt) that faded with appliance wear.⁷⁴ Several texts used or suggested using compliance indicators by growing patients to aid in patient monitoring.^{18,41,44,51} Another technique proposed by Pavoni et al. was to consider smaller increments of mandibular advancement, which may provide less discomfort and therefore increase compliance.³⁹

Growing populations

Prior to CAT plus MA treatment, fixed or removable functional appliances provided a method for the early management of a Class II malocclusion. Nine of the 16 cohort studies had comparison groups which provided valuable insight into the efficacy and mechanisms of CAT compared to traditional functional appliances. Comparing their test group to a control of non-treated individuals, Al Subaie et al. corroborated the findings of several of the previous case reports and determined that CAT plus MA produced a predominantly skeletal change in favour of Class II correction.¹⁹ However, compared to the TB appliance, CAT plus MA showed slight variances in efficacy and in the end result. Caruso et al. noted that while both appliances effectively reduced ANB values and overjet, the TB “demonstrated a higher efficacy in increasing mandibular dimensions”; however, CAT provided better control of the upper incisors.³¹ Blackham’s retrospective cohort study found that while there were few significant differences in the skeletal changes produced by a TB versus CAT plus MA, increased mandibular growth in the TB group occurred compared to the CAT plus MA and control groups.⁴⁹ It was further noted that treatment using CAT plus MA resulted in less tipping of the lower incisors.⁴⁹ A comprehensive analysis by Wu et al. compared CAT to the vanBeek appliance, the Herbst appliance and the TB.⁴⁶ The comparison showed that all were effective in Class II correction by inducing forward growth of the mandible; however, it was the vanBeek appliance that produced the greatest skeletal effects and also exhibited significant lower incisor control.⁴⁶ The Herbst appliance showed skeletal change with effective upper molar distalisation, while the TB showed both skeletal and dental changes and lower incisor proclination. Although CAT plus MA corrected an overjet mainly via dentoalveolar effects, it also provided good lower incisor control and the ability to perform multiple alignments in conjunction with MA.⁴⁶

Comparisons of the numerous studies between CAT modalities and traditional functional appliances, determined that functional appliances may produce a greater skeletal effect, and forward growth of the mandible, and therefore, may be beneficial in retrognathic Class II cases. However, the projected

growth of an individual must be considered along with the appliance’s potential to worsen the mandibular plane angle or contribute to a clockwise mandibular rotation, in which case, CAT may prove to be a preferred option. Greater demands for aesthetics, lower incisor control as well as vertical control may also favour the use of CAT.

The treatment of growing patients produced a wider range of CAT treatment approaches, perhaps due to the growth potential. Upper molar distalisation using the “DF2 protocol” comprised of a treatment course of two distinct phases, was reported in several studies.^{20,26} The primary stage focused on sagittal alignment using Class II elastics, to rotate and distalise the upper molars; the second phase involved full arch CAT to correct other malalignments that may be present.^{20,26} The main benefit noted was better vertical control during sagittal correction compared to the Carriere Distalizer (Henry Schein Orthodontics, NY USA). Otis found that poor correlation between the amount of Class II correction and treatment duration might indicate the advantages of the DF2 protocol in cases that required significant Class II correction.²⁶ Ferris and Rungcharassaeng,²⁰ noted that the use of the DF2 protocol resulted in a headgear treatment effect, in which a backward force applied to the maxilla restricted its growth.⁷⁵ This may be advantageous in individuals with a hyperplastic maxilla, but it was also noted that there was a lack of discernible change in sagittal mandibular position. This may indicate a difference in effect between DF2 and functional appliances.

In CAT plus MA, clear aligners either included posterior precision wings to posture the mandible forward, or they relied on incisor position; the F22 Young Appliance (Sweden and Martina, Due Carrare (PD), Italy) consisted of a clear aligner with a “customisable block” on the palatal surface of the upper incisors to fit behind the lower aligner and advance the mandible.²² The F22 Young Appliance may be used in conjunction with other techniques and appliances such as a rapid palatal expander.²² Invisalign Teen (Align Technology, Inc., Santa Clara, CA, USA) was used in studies that involved distalisation and/or MA/precision wings^{28,41,51} although the clear aligners were identical to those used in other Invisalign treatment plans, the aligners included a compliance indicator component and

treatment plans tended to allow for tooth eruption and also include a mostly elastic-free option.^{41,51}

Two concerns related to CAT were identified which included difficulty in engaging the precision wings in CAT plus MA appliances and a resulting temporary open bite (either posterior or lateral) during treatment. The issue of compliance during CAT was seen as a common disadvantage of treatment.^{76,77} Furthermore, elastics as an auxiliary in Class II correction also required compliance.⁷⁸ The precision wing engagement has further potential implications regarding patient compliance and may ultimately affect treatment time and efficacy. Temporary open bites may require further aligners which may also increase treatment time.

Non-growing populations

Prior to design advancements in CAT, functional appliances were the main treatment option for Class II correction. Within the non-growing patient studies, two reports compared CAT to conventional therapies of Class II correction. While data on treatment time and efficacy between the two groups were not specifically mentioned, Bajaj provided valuable insight into the dento-skeletal changes between the two groups as their study found that there were less vertical tooth moments in the CAT group compared to the fixed appliance group.⁶⁹ Additionally, the findings showed increased incisor intrusion in the CAT group compared to increased protrusion and the extrusion seen in the fixed appliance group.⁶⁹ The findings support the benefits of vertical and lower incisor control identified in numerous studies. However, it was noted that the results of the CAT group were obtained from one practitioner compared to the results of the fixed appliance group which were obtained from multiple sources, implying differences in treatment execution and techniques.⁶⁹

The advancements and progression of techniques have enhanced the efficacy of CAT when applied in the treatment of Class II malocclusions. Of the studies of non-growing patients, 17 achieved the treatment objectives or mentioned correction to Class I. No single treatment method was shown to be superior, as there were multiple treatment options which achieved the planned objectives,^{54–56,59,60,63,69} and recorded as CAT (mandibular jump),⁵⁷ CAT (sequential distalisation),^{57,65–68,71,72} CAT plus surgery

plus TADs,⁵³ CAT plus TADs,⁶² CAT plus MA (with photobiomodulation (PBM)).⁶⁴ Three of the five studies which showed a treatment time of ≤ 12 months assessed unilateral Class II cases,^{55,60,68} while one was a bilateral half-unit (end-to-end molar) Class II case.⁶⁴ However, within the five studies, there were two which employed CAT,^{55,60} two with CAT (sequential distalisation),^{58,68} and one with CAT plus MA with PBM.⁶⁴ While it is evident that less complex cases may lead to shorter treatment times, there were no obvious advantages between treatment modalities and efficacy/treatment times.

General alignment of the arches and sequential distalisation were more commonly employed rather than CAT plus MA due to a lack of growth potential in adult patients. However, a case report described the successful treatment of an adult patient who presented with a Class II malocclusion by using CAT plus MA and PBM.⁶⁴ The combination of clear aligners with MA wings and the use of a PBM device worn for five minutes in each arch daily (10 minutes in total), led to successful aligner changes every three to four days. The total active treatment time was seven months, resulting in a Class I occlusion as well as a Class I skeletal relationship (verified by lateral cephalometric measurements).⁶⁴ Although further research is needed to corroborate the findings, this pioneering technique may prove to be a solution to overcome the challenge of treating skeletal Class II cases in non-growing patients.

A significant issue when treating Class II deep bite cases is the challenge of creating and preserving anchorage. While temporary anchorage devices (TADs) have established use alongside fixed appliances,⁷⁹ it is a relatively newer technique in cases treated using CAT.^{53,62} Further complications can arise when treating extraction cases due to the tooth tipping characteristic of CAT, bodily movements can be a challenge in extraction cases and may even contribute to lengthier treatment times than fixed appliances.⁸ A case report addressed both of these issues and presented a deep bite extraction case in which treatment consisted of the removal of the upper first premolars and the bilateral placement of TADs between the upper lateral incisors and canines. Buttons on the upper lateral incisors provided attachments for elastics looped to the TADs. Supplemental elastics were also attached between hooks on the upper canines and buttons on the lower

first molars. The authors noted that the deep-bite and a slight right-side canine Class II relationship persisted after the initial 21 months of treatment but after 31 months, all the treatment objectives were met.⁶² While there has been an increase in the use of novel adjuncts, further research of these newer techniques is required to broaden their scope and applicability.

While compliance is a well-known issue across any removable appliance, the known disadvantage of CAT within non-growing individuals was poor efficacy of tooth movement.⁵⁹ Clear aligners are created using a digital scan and online planning, which inherently involves a significant reliance on technology. Software programs such as the Invisalign ClinCheck system (Align Technology, Inc., Santa Clara, CA) provide an online platform for practitioners to plan their case and desired outcome and subsequently produce aligners based on the digitally predicted outcome.⁷⁰ While the success of orthodontic treatment is usually evaluated clinically by a finished Class I occlusion,¹ the American Board of Orthodontics Objective Grading System (ABO OGS) provides a more thorough and objective measurement of treatment success.⁸⁰ Three studies mentioned poor predictability/efficacy of tooth movement following a comparison of pre-treatment and either predicted or post-treatment results by the ABO-OGS.^{58,61,70} Alternatively, while predictions and actual outcomes may be compared through software programs, three studies discussed an inconsistency between the predicted versus the actual outcome.^{65,67,72} Of the six studies which discussed poor efficacy/predictability of tooth movement,^{58,61,65,67,70,72} five were in relation to sequential distalisation.^{58,61,65,67,72} This implies that sequential distalisation alone may be inadequate for correcting a Class II malocclusion. Two studies discussed a discrepancy between the predicted and actual outcome^{65,72} and other studies included planned overcorrection to try to avoid these discrepancies.⁷⁰ Overcorrection is not a novel concept and is commonly planned into aligner treatment to increase treatment efficacy.⁸¹ A failure to meet treatment objectives due to poor tooth movement may also add to the need for additional aligners. One study from the USA included a mix of growing and non-growing individuals⁸² and discussed creative adjuncts including traditional TADs (particularly in adult patients in whom more anchorage may be required due to the lack of growth potential), as well as a palatal TADs with a mesially extending “power

arm” incorporating a closed coil retraction spring to help guide the clear aligner tray to distalise an entire quadrant.⁸² The general findings were consistent with previous studies in stating the benefit of aesthetics but also mentioning the major issue of compliance.⁸² However, the study also recommended the use of TADs to increase distalisation predictability.⁸² Further research on this technique and the issue of predictability may therefore be beneficial. Predictability within growing patients was not reported in depth which also creates a demanding area of future research, particularly as growth patterns may be a compounding treatment factor.

As a removable appliance, the issue of compliance with CAT cannot be ignored and was mentioned in 11 of the 21 studies of non-growing populations. Poor compliance may result in failed treatment outcomes, a need for further refinements, and/or a prolonged treatment duration.

Limitations

There are a number of limitations associated with the present study. Firstly, individual growth rates differ and it is difficult to account for this in Class II treatment unless the growth stage of an individual is determined.⁸³ Growth status using the cervical vertebral maturation (CVM) method was not always stated in each text and so studies were divided into growing and non-growing patients based on whether participants were above or below 18 years of age. A number of studies may have therefore been unnecessarily excluded when there was mixed data pertaining to growing and non-growing individuals. Secondly, studies in which CAT was used for Class II correction with adjuncts (such as surgery/functional appliances) were only included if the individual/population still had a Class II malocclusion prior to the commencement of the CAT treatment phase. If an adjunct such as surgery or a functional appliance was used to completely correct the Class II malocclusion prior to CAT, the study was excluded. Finally, separation by severity, dental or skeletal, or division of a Class II malocclusion may yield valuable results and may help improve the orthodontic understanding of Class II correction using CAT.

Conclusion

- For both growing and non-growing patients, Class II correction using CAT commonly involved

modalities such as mandibular advancement and maxillary distalisation, often supplemented with auxiliary bite ramps or elastics.

- Benefits included good incisor and vertical control, suggesting that CAT may be a beneficial treatment option when correcting Class II malocclusions.
- Simultaneous tooth movements in conjunction with MA may be a benefit for growing patients, although it should be noted that too many simultaneous tooth movements may compromise treatment outcomes.
- The limitations of CAT in growing populations include challenges with engaging precision wings, a resulting temporary posterior open bite, as well as the added need for elastic compliance along with the general compliance required for CAT.
- The major limitation of CAT within non-growing populations was the poor efficacy and predictability of tooth movement, especially in sequential distalisation. This may have implications on the need for planned overcorrection, additional aligners, increased treatment time or even the inability to completely correct the Class II malocclusion.

- No studies mentioned the amount of Class II correction as a limitation for CAT.

Conflict of interest

The authors declare that there is no conflict of interest.

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Appendix I. Search strategy and data base search terms used

PubMed	
Clear aligners	Class II Malocclusions
("Clear Aligner*" [tw] OR "Clear Aligner Therapy" [tw] OR "CAT" [tw] OR "32 Watts Clear Aligner*" [tw] OR "360 美牙隐形矫正" OR [tw] "ACE Aligner*" [tw] OR "Angelalign 时代天使隐形矫正" [tw] OR "Argen" [tw] OR "CA Clear Aligner*" [tw] OR "Clarity Aligner*" [tw] OR "Clarus Clear Aligner*" [tw] OR "Clear Correct" [tw] OR "Isignia Clearguide System" [tw] OR "Clearline Aligner*" [tw] OR "Clearlyaligner*" [tw] OR "ClearPath" [tw] OR "ClearPath Orthodontics" [tw] OR "ClearSmile*" [tw] OR "Clear X" [tw] OR "Coast Clear Aligner*" [tw] OR "ddhaim Clear 디디하임 클리어" [tw] OR "Dr. Clear Aligner*" [tw] OR "Easysmile*" [tw] OR "eCigner 이클라이너" [tw] OR "EON Aligner*" [tw] OR "F22 Aligner*" [tw] OR "Hibeauty 隐秀隐形矫正" [tw] OR "Inman Aligner*" [tw] OR "Invisalign" [tw] OR "iROK" [tw] OR "Joy Aligner*" [tw] OR "K Clear" [tw] OR "NoviClear" [tw] OR "Nuvola" [tw] OR "ODS Aligner*" [tw] OR "Orthocaps TwinAligner System*" [tw] OR "OrthoFX" [tw] OR "OrthoSnap" [tw] OR "Pure Smiles Online" [tw] OR "Refine Complete Aligner System" [tw] OR "Reveal Clear Aligner*" [tw] OR "RX Aligner*" [tw] OR "See-Through Aligner 시스루 얼라이너" [tw] OR "Simpli 5" [tw] OR "Sino Dental Lab" [tw] OR "SLX Clear Aligner*" [tw] OR "Smile Styler" [tw] OR "Smilealign 适乐美" [tw] OR "Smileign" [tw] OR "SmileTRU" [tw] OR "smilii" [tw] OR "Spark Clear Aligner System" [tw] OR "SureSmile*" [tw] OR "Trioclear" [tw] OR "Uniform Teeth" [tw] OR "V-Clear Aligner*" [tw] OR "Vincialign 达芬奇隐形矫正" [tw] OR "Whitesmile Clear" [tw] OR "Wonder Smile*" OR "Zenyum")	("Malocclusion, Angle Class II" [mh] OR "Overbite" [mh] OR "Class II Malocclusion" [tw] OR "Class II Malocclusions" [tw] OR "Class II" [tw] OR "Class 2" [tw] OR "Class 2 Malocclusion*" [tw] OR "Angle's Class II" [tw] OR "Angle's Class 2" [tw] OR "Angle Class II" OR "Angle Class 2" [tw] OR "Overbite" [tw] OR "Overjet" [tw])
EMBASE (Ovid)	
Clear Aligners	Class II Malocclusions
(Orthodontic Aligner.sh. OR ("Clear Aligner*" OR "Clear Aligner Therapy" OR "CAT" OR "32 Watts Clear Aligner*" OR "360 美牙隐形矫正" OR "ACE Aligner*" OR "Angelalign 时代天使隐形矫正" OR "Argen" OR "CA Clear Aligner*" OR "Clarity Aligner*" OR "Clarus Clear Aligner*" OR "Clear Correci" OR "Isignia Clearguide System" OR "Clearline Aligner*" OR "Clearlyaligner*" OR "ClearPath" OR "ClearPath Orthodontics" OR "ClearSmile*" OR "Clear X" OR "Coast Clear Aligner*" OR "ddhaim Clear 디디하임 클리어" OR "Dr. Clear Aligner*" OR "Easysmile*" OR "eCigner 이클라이너" OR "EON Aligner*" OR "F22 Aligner*" OR "Hibeauty 隐秀隐形矫正" OR "Inman Aligner*" OR "Invisalign" OR "iROK" OR "Joy Aligner*" OR "K Clear" OR "NoviClear" OR "Nuvola" OR "ODS Aligner*" OR "Orthocaps TwinAligner System*" OR "OrthoFX" OR "OrthoSnap" OR "Pure Smiles Online" OR "Refine Complete Aligner System" OR "Reveal Clear Aligner*" OR "RX Aligner*" OR "See-Through Aligner 시스루 얼라이너" OR "Simpli 5" OR "Sino Dental Lab" OR "SLX Clear Aligner*" OR "Smile Styler" OR "Smilealign 适乐美" OR "Smileign" OR "SmileTRU" OR "smilii" OR "Spark Clear Aligner System" OR "SureSmile*" OR "Trioclear" OR "Uniform Teeth" OR "V-Clear Aligner*" OR "Vincialign 达芬奇隐形矫正" OR "Whitesmile Clear" OR "Wonder Smile*" OR "Zenyum").mp)	(Exp Angle Class II Malocclusion OR ("Class II Malocclusion" OR "Class II Malocclusions" OR "Class 2 Malocclusion*" OR "Class II" OR "Class 2" OR "Angle's Class II" OR "Angle Class II" OR "Angle's Class 2" OR "Angle Class 2" OR "Overbite" OR "Overjet").mp)

Appendix I. Continued

PubMed	
Web of Science	
Clear Aligners	Class II Malocclusions
(TS=("Clear Aligner*" OR "Clear Aligner Therapy" OR "CAT" OR "32 Watts Clear Aligner*" OR "360 美牙隐形矫正" OR "ACE Aligner*" OR "Angelalign 时代天使隐形矫正" OR "Argen" OR "CA Clear Aligner*" OR "Clarity Aligner*" OR "Clarus Clear Aligner*" OR "Clear Correct" OR "Isignia Clearguide System" OR "Clearline Aligner*" OR "Clearlyaligner*" OR "ClearPath" OR "ClearPath Orthodontics" OR "ClearSmile*" OR "Clear X" OR "Coast Clear Aligner*" OR "ddhaim Clear 디디하임 클리어" OR "Dr. Clear Aligner*" OR "Easysmile*" OR "eCIGNER 이클라이너" OR "EON Aligner*" OR "F22 Aligner*" OR "Hibeauty 隐秀隐形矫正" OR "Inman Aligner*" OR "Invisalign" OR "iROK" OR "Joy Aligner*" OR "K Clear" OR "NoviClear" OR "Nuvola" OR "ODS Aligner*" OR "Orthocaps TwinAligner System*" OR "OrthoFX" OR "OrthoSnap" OR "Pure Smiles Online" OR "Refine Complete Aligner System" OR "Reveal Clear Aligner*" OR "RX Aligner*" OR "See-Through Aligner 시스루 얼라이너" OR "Simpli 5" OR "Sino Dental Lab" OR "SLX Clear Aligner*" OR "Smile Styler" OR "Smilealign 适乐美" OR "Smilelign" OR "SmileTRU" OR "smilii" OR "Spark Clear Aligner System" OR "SureSmile*" OR "Trioclear" OR "Uniform Teeth" OR "V-Clear Aligner*" OR "Vincialign 达芬奇隐形矫正" OR "Whitesmile Clear" OR "Wonder Smile*" OR "Zenyum"))	(TS=("Class II Malocclusion" OR "Class II Malocclusions" OR "Class 2 Malocclusion*" OR "Class 2" OR "Class II" OR "Angle's Class II" OR "Angle Class II" OR "Angle's Class 2" OR "Angle Class 2" OR "Overjet" OR "Overbite"))
SCOPUS	
Clear Aligners	Class II Malocclusions
TITLE-ABS-KEY("Clear Aligner*" OR "Clear Aligner Therapy" OR "CAT" OR "32 Watts Clear Aligner*" OR "360 美牙隐形矫正" OR "ACE Aligner*" OR "Angelalign 时代天使隐形矫正" OR "Argen" OR "CA Clear Aligner*" OR "Clarity Aligner*" OR "Clarus Clear Aligner*" OR "Clear Correct" OR "Isignia Clearguide System" OR "Clearline Aligner*" OR "Clearlyaligner*" OR "ClearPath" OR "ClearPath Orthodontics" OR "ClearSmile*" OR "Clear X" OR "Coast Clear Aligner*" OR "ddhaim Clear 디디하임 클리어" OR "Dr. Clear Aligner*" OR "Easysmile*" OR "eCIGNER 이클라이너" OR "EON Aligner*" OR "F22 Aligner*" OR "Hibeauty 隐秀隐形矫正" OR "Inman Aligner*" OR "Invisalign" OR "iROK" OR "Joy Aligner*" OR "K Clear" OR "NoviClear" OR "Nuvola" OR "ODS Aligner*" OR "Orthocaps TwinAligner System*" OR "OrthoFX" OR "OrthoSnap" OR "Pure Smiles Online" OR "Refine Complete Aligner System" OR "Reveal Clear Aligner*" OR "RX Aligner*" OR "See-Through Aligner 시스루 얼라이너" OR "Simpli 5" OR "Sino Dental Lab" OR "SLX Clear Aligner*" OR "Smile Styler" OR "Smilealign 适乐美" OR "Smilelign" OR "SmileTRU" OR "smilii" OR "Spark Clear Aligner System" OR "SureSmile*" OR "Trioclear" OR "Uniform Teeth" OR "V-Clear Aligner*" OR "Vincialign 达芬奇隐形矫正" OR "Whitesmile Clear" OR "Wonder Smile*" OR "Zenyum")	TITLE-ABS-KEY("Class II Malocclusion" OR "Class II Malocclusions" OR "Class 2 Malocclusion*" OR "Class II" OR "Class 2" OR "Angle's Class II" OR "Angle Class II" OR "Angle's Class 2" OR "Angle Class 2" OR "Angle Class II" OR "Overjet" OR "Overbite")

Appendix I. Continued

PubMed	
ProQuest Central	
Clear Aligners	Class II Malocclusions
ABSTRACT("Clear Aligner*" OR "Clear Aligner Therapy" OR "CAT" OR "32 Watts Clear Aligner*" OR "360 美牙隐形矫正" OR "ACE Aligner*" OR "Angelalign 时代天使隐形矫正" OR "Argen" OR "CA Clear Aligner*" OR "Clarity Aligner*" OR "Clarus Clear Aligner*" OR "Clear Correct" OR "Isignia Clearguide System" OR "Clearline Aligner*" OR "Clearlyaligner*" OR "ClearPath" OR "ClearPath Orthodontics" OR "ClearSmile*" OR "Clear X" OR "Coast Clear Aligner*" OR "ddhaim Clear 디디하임 클리어" OR "Dr. Clear Aligner*" OR "Easysmile*" OR "eCaligner 이클라이너" OR "EON Aligner*" OR "F22 Aligner*" OR "Hibeauty 隐秀隐形矫正" OR "Inman Aligner*" OR "Invisalign" OR "iROK" OR "Joy Aligner*" OR "K Clear" OR "NoviClear" OR "Nuvola" OR "ODS Aligner*" OR "Orthocaps TwinAligner System*" OR "OrthoFX" OR "OrthoSnap" OR "Pure Smiles Online" OR "Refine Complete Aligner System" OR "Reveal Clear Aligner*" OR "RX Aligner*" OR "See-Through Aligner 시스템 열라이너" OR "Simpli 5" OR "Sino Dental Lab" OR "SLX Clear Aligner*" OR "Smile Styler" OR "Smilealign 适乐美" OR "Smilelign" OR "SmileTRU" OR "smilii" OR "Spark Clear Aligner System" OR "SureSmile*" OR "Trioclear" OR "Uniform Teeth" OR "V-Clear Aligner*" OR "Vincialign 达芬奇隐形矫正" OR "Whitesmile Clear" OR "Wonder Smile*" OR "Zenyum")	ABSTRACT("Class II Malocclusion" OR "Class II Malocclusions" OR "Class 2 Malocclusion*" OR "Class II" OR "Class 2" OR "Angle's Class II" OR "Angle Class II" OR "Angle's Class 2" OR "Angle Class 2" OR "Overjet" OR "Overbite")
DOSS (Dentistry and Oral Sciences Source)	
Clear Aligners	Class II Malocclusions
AB("Clear Aligner*" OR "Clear Aligner Therapy" OR "CAT" OR "32 Watts Clear Aligner*" OR "360 美牙隐形矫正" OR "ACE Aligner*" OR "Angelalign 时代天使隐形矫正" OR "Argen" OR "CA Clear Aligner*" OR "Clarity Aligner*" OR "Clarus Clear Aligner*" OR "Clear Correct" OR "Isignia Clearguide System" OR "Clearline Aligner*" OR "Clearlyaligner*" OR "ClearPath" OR "ClearPath Orthodontics" OR "ClearSmile*" OR "Clear X" OR "Coast Clear Aligner*" OR "ddhaim Clear 디디하임 클리어" OR "Dr. Clear Aligner*" OR "Easysmile*" OR "eCaligner 이클라이너" OR "EON Aligner*" OR "F22 Aligner*" OR "Hibeauty 隐秀隐形矫正" OR "Inman Aligner*" OR "Invisalign" OR "iROK" OR "Joy Aligner*" OR "K Clear" OR "NoviClear" OR "Nuvola" OR "ODS Aligner*" OR "Orthocaps TwinAligner System*" OR "OrthoFX" OR "OrthoSnap" OR "Pure Smiles Online" OR "Refine Complete Aligner System" OR "Reveal Clear Aligner*" OR "RX Aligner*" OR "See-Through Aligner 시스템 열라이너" OR "Simpli 5" OR "Sino Dental Lab" OR "SLX Clear Aligner*" OR "Smile Styler" OR "Smilealign 适乐美" OR "Smilelign" OR "SmileTRU" OR "smilii" OR "Spark Clear Aligner System" OR "SureSmile*" OR "Trioclear" OR "Uniform Teeth" OR "V-Clear Aligner*" OR "Vincialign 达芬奇隐形矫正" OR "Whitesmile Clear" OR "Wonder Smile*" OR "Zenyum")	AB("Class II Malocclusion" OR "Class II Malocclusions" OR "Class 2 Malocclusion*" OR "Class II" OR "Class 2" OR "Angle's Class II" OR "Angle Class II" OR "Angle's Class 2" OR "Angle Class 2" OR "Overjet" OR "Overbite")

Appendix II. Orthodontic websites included in gray literature search and search terms used

List obtained from Australian Society of Orthodontics Site, Oct 2023

World Federation of Orthodontists - <https://www.wfo.org>
 Australasian Orthodontic Board - http://aob.aso.org.au/AOB/AOB_docs/AOB.htm
 American Association of Orthodontists - <https://aaoinfo.org>
 Association of Orthodontists (Singapore) - <http://www.aos.org.sg>
 Bangladesh Orthodontic Society - <https://sites.google.com/site/sites/system/errors/WebpageNotFound?path=%2Fbangladeshorthodonticsociety%2F>
 BBUSO-UPBSUO - <https://bbno.be>
 Berufsverband der Deutschen Kieferorthopäden - <https://www.bdk-online.org>
 Brazilian Association of Orthodontics-Facial Orthopedics - <http://www.abor.org.br>
 British Orthodontic Society - <http://www.bos.org.uk>
 California Association of Orthodontists - <https://www.caortho.org>
 Canadian Association of Orthodontists - <https://www.cao-aco.org>
 Charles Tweed Foundation - <http://www.tweedortho.com>
 Czech Orthodontic Society - <http://www.orthodont-cz.cz/en/>
 Dental Specialists Society of WA - <https://dsswa.org.au>
 Dutch Association of Orthodontists - <https://www.orthodontist.nl>
 Egyptian Orthodontic Society - <https://egyptortho.org>
 Electronic Study Club for Orthodontics - <https://dentistry.uic.edu/cms/One.aspx?portalId=211408&pageId=316664>
 European Orthodontic Society - <https://eoseurope.org>
 German Association of Orthodontists (KFO-IG) - <https://www.kfo-ig.de>
 German Orthodontic Society - <http://www.dgkfo.de>
 Greek Orthodontic Society - <http://www.grortho.gr>
 Indian Orthodontic Society - <http://www.iosweb.net>
 Indonesian Orthodontic Association - <http://ikorti-iao.com>
 Japanese Association of Orthodontists - <https://www.jpao.jp/foreign/en/>
 Korean Association of Orthodontists - <http://www.kao.or.kr>
 Malaysian Association of Orthodontists - <https://www.mao.org.my>
 New Zealand Association of Orthodontists - <https://www.orthodontists.org.nz>
 Ontario Association of Orthodontists - <http://www.oao.on.ca>
 Pacific Coast Society of Orthodontists - <http://www.pcsortho.org>
 Association of Phillipine Orthodontists - <http://www.apo.com.ph>
 Singapore Association of Orthodontists - <https://www.aos.org.sg>
 Sociedade GaÙcha de Ortodonti - <http://www.sogaor.org.br>
 Sri Lanka Orthodontic Society - <http://srilankaorthodonticsociety.com>
 South African Society of Orthodontists - <http://www.saso.co.za>
 Taiwan Association of Orthodontists - <https://www.tao.org.tw>
 Thai Association of Orthodontists - <https://www.thaiortho.org>

Orthodontic Websites Search Terms.

"Clear Aligner*" OR "Clear Aligner Therapy" OR "CAT" AND "Class II" OR "Class II Malocclusion" or "Overjet" or "Overbite".

Appendix III. Clear aligner company sites included in gray literature search and search terms used

List of clear aligner companies as per Shi et. al 2022 (6)

1. 32 Watts Clear Aligners
 2. 360 美牙隐形矫正
 3. ACE Aligners
 4. AIRNIVOL
 5. Angelalign 时代天使隐形矫正
 6. Argen
 7. CA Clear Aligner
 8. Clarity Aligners
 9. Clarus Clear Aligners
 10. Clear Correct
 11. Insignia Clearguide System
 12. Clearline Aligners
 13. Clearlyaligners
 14. ClearPath
 15. ClearPath Orthodontics
 16. ClearSmile
 17. Clear X
 18. Coast Clear Aligners
 19. ddhaim clear 디디하임 클리어
 20. Dr. Clear Aligner
 21. Easysmile
 22. eCaligner 이클라이너
 23. eon Aligners
 24. F22 Aligners
 25. Hibeauty 隐秀隐形矫正
 26. Inman Aligner
 27. Invisalign
 28. iROK
 29. Joy Aligner
 30. K Clear
 31. Noviclear
 32. Nuvola
 33. ODS Aligners
 34. Orthocaps TwinAligner System
 35. OrthoFX
 36. OrthoSnap
 37. Pure Smiles Online
 38. Refine Complete Aligner System
 39. Reveal Clear Aligners
 40. RX Aligners
 41. See-Through Aligner 시스루얼라이너
 42. simpli 5
 43. Sino Dental Lab
 44. SLX Clear Aligners
 45. Smile Styler
 46. Smilealign 适乐美
 47. Smileign
 48. SmileTRU
 49. smilii
 50. Spark Clear Aligner System
 51. SureSmile
 52. Trioclear
 53. Uniform Teeth
 54. V-Clear Aligners
 55. Vincialign 达芬奇隐形矫正
 56. Whitesmile Clear
 57. Wonder Smile
 58. Zenyum
-

Do-it-yourself aligner systems have been omitted from the original list.

Clear Aligner Company Websites Search Terms Used.

"Class II" OR "Class II Malocclusion" or "Overjet" or "Overbite".

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