



**INSTITUTO UNIVERSITÁRIO EGAS MONIZ**

**MESTRADO INTEGRADO EM MEDICINA DENTÁRIA**

**POSSIBILITIES AND LIMITATIONS OF ORTHODONTIC TREATMENT  
WITH CLEAR ALIGNERS**

Trabalho submetido por  
**Sirine Gargouri**  
para a obtenção do grau de Mestre em Medicina Dentária

**Novembro de 2022**





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**Prof. Doutora Iman Bugaighis**

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## **DEDICATORY**

*To My Dear Husband,  
Majdeddine REBAI*



## ACKNOWLEDGMENTS

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## RESUMO

Actualmente, a procura de tratamentos estéticos está a aumentar, mais pessoas procuram alternativas aos aparelhos ortodônticos fixos, tais como os alinhadores invisíveis. Ao longo da última década, os alinhadores invisíveis evoluíram e ganharam imensa popularidade.

O objetivo desta revisão de literatura foi avaliar criticamente a eficiência e eficácia da terapia com alinhadores invisíveis, analisando as possibilidades e limitações, bem como as vantagens e desvantagens dos alinhadores invisíveis em comparação com a terapia com aparelhos fixos.

A questão de investigação do estudo "o que podemos e não podemos fazer com alinhadores invisíveis?" foi elaborada de acordo com o método PICO: População: pacientes com necessidade de tratamento ortodôntico, Intervenção: tratamento ortodôntico com alinhadores invisíveis, Comparação: tratamento ortodôntico convencional com aparelhos fixos, Resultado: eficácia do tratamento. A pesquisa dos artigos foi realizada utilizando a literatura publicada em inglês, português e francês, entre 2000 e 2022, utilizando os seguintes motores de busca: PubMed, Google Scholar, Cochrane, e livros relevantes.

A análise da literatura estudada mostrou que os alinhadores invisíveis podem ser uma solução estética e confortável adequada para a correção de maloclusões leves a moderadas.

No entanto, estudos de alto nível de qualidade ainda são necessários para tirar conclusões firmes sobre a eficiência e eficácia dos tratamentos realizados com alinhadores invisíveis.

**Palavras-chave:** Alinhadores invisíveis, Invisalign, Aparelhos Fixos, Tratamento ortodôntico convencional.



## **ABSTRACT**

Nowadays, the demand for aesthetic treatments is increasing, more people are looking for alternatives to fixed orthodontic appliances, such as clear aligners. Over the last decade, clear aligners have evolved and gained immense popularity.

The objective of this literature review was to critically appraise the efficiency and effectiveness of clear aligner therapy by analysing the possibilities and limitations, as well as the advantages and disadvantages of clear aligners in comparison with fixed appliance therapy.

The research question of the study “ what can we do and cannot do with clear aligners? ” was elaborated according to the PICO method: Population: patients in need for orthodontic treatment, Intervention: orthodontic treatment with clear aligners, Comparison: conventional orthodontic treatment with fixed appliances, Outcome: effectiveness of treatment. The search for the articles answering the question was performed using the relevant related evidence based published literature in English, Portuguese and French languages between year 2000 to 2022 using the following search engines: PubMed, Google Scholar, Cochrane, and relevant books on the subject.

The analysis of the studied literature showed that clear aligners could be a suitable aesthetic and comfortable solution for the correction of mild to moderate malocclusions.

However, studies of high quality level are still required to draw firm conclusions about the efficiency and effectiveness of treatments performed with clear aligners.

**Keywords:** Clear Aligners; Invisalign; Fixed Appliances; Conventional Orthodontic treatment.



## **RESUME**

De nos jours, la demande de traitements esthétiques est en augmentation. De plus en plus de personnes recherchent des alternatives aux appareils orthodontiques fixes, comme les aligneurs transparents. Au cours de la dernière décennie, les aligneurs transparents ont évolué et gagné une immense popularité.

L'objectif de cette revue de la littérature était d'évaluer de manière critique l'efficacité et l'efficacit  du traitement par aligneurs transparents en analysant les possibilit s et les limites, ainsi que les avantages et les inconv nients des aligneurs transparents par rapport au traitement par appareils fixes.

La question de recherche de l' tude " Que peut-on faire et ne pas faire avec les aligneurs transparents? " a  t   labor e selon la m thode PICO ; Population: patients ayant besoin d'un traitement orthodontique, Intervention: traitement orthodontique avec aligneurs transparents, Comparaison: traitement orthodontique conventionnel avec appareils fixes, R sultat: efficacit  du traitement. La recherche d'articles r pondant   la question a  t  effectu e en utilisant la litt rature publi e en anglais, portugais et fran ais entre 2000 et 2022, en utilisant les moteurs de recherche suivants : PubMed, Google Scholar, Cochrane, et des livres pertinents sur le sujet.

L'analyse de la litt rature  tudi e a montr  que les aligneurs transparents pourraient  tre une solution esth tique et confortable pour la correction des malocclusions l g res   mod r es.

Cependant, des  tudes de haute qualit  sont encore n cessaires pour tirer des conclusions solides sur l'efficacit  des traitements r alis s avec les aligneurs transparents.

**Mots cl s :** Aligneurs transparents; Invisalign ; Appareils fixes ; Traitement orthodontique conventionnel.



## INDEX

<b>I. INTRODUCTION.....</b>	<b>15</b>
<b>II. DEVELOPMENT.....</b>	<b>17</b>
<b>2.1. History of clear aligners .....</b>	<b>17</b>
<b>2.2. Characteristics of clear aligners .....</b>	<b>21</b>
2.2.1. Composition of aligner materials and manufacturing method .....	21
2.2.2. Gingival margin design .....	22
2.2.3. Material thickness.....	23
<b>2.3. Attachments and auxiliary techniques.....</b>	<b>23</b>
2.3.1. Attachments.....	23
2.3.2. Auxiliary techniques.....	26
<b>2.4. Biomechanics of clear aligners.....</b>	<b>27</b>
<b>2.5. Possible treatments with clear aligners.....</b>	<b>30</b>
2.5.1. Orthodontic treatment of growing patients.....	31
2.5.2. Mild to moderate malocclusions.....	32
2.5.3. Crowding cases.....	32
2.5.4. Sagittal plan .....	33
2.5.5. Vertical plan .....	33
2.5.6. Transversal plan.....	33
2.5.7. Orthognathic surgery procedures.....	33
<b>2.6. Limitations of clear aligner therapy.....</b>	<b>34</b>
2.6.1. Final occlusion.....	34
2.6.2. Post treatment relapse .....	35
2.6.3. Severe cases .....	35
2.6.4. Tooth movement predictability .....	35
<b>2.7. Retention post clear aligner therapy .....</b>	<b>36</b>
<b>2.8. Advantages of clear aligners .....</b>	<b>37</b>
2.8.1. Indications .....	37
2.8.2. Root resorption .....	37
2.8.3. Oral health .....	38
2.8.4. Aesthetics .....	38
2.8.5. Comfort.....	39

2.8.6.	Perceived pain.....	39
2.8.7.	Motivation for orthodontic treatment .....	40
2.8.8.	Treatment duration and number of appointments .....	40
2.8.9.	Emergencies.....	40
2.8.10.	Profitability.....	40
<b>2.9.</b>	<b>Disadvantages of clear aligners .....</b>	<b>41</b>
2.9.1.	Efficacy.....	41
2.9.2.	Patient compliance.....	41
2.9.3.	Masticatory muscle activity.....	41
2.9.4.	Speech problems.....	41
2.9.5.	Material deterioration and loss .....	42
2.9.6.	Treatment cost .....	42
<b>2.10.</b>	<b>Comparison between fixed appliances and clear aligners.....</b>	<b>42</b>
<b>2.11.</b>	<b>Keys to successful treatment with clear aligners.....</b>	<b>44</b>
2.11.1.	Adequate patient selection.....	44
2.11.2.	Effective patient communication.....	44
2.11.3.	Clear treatment goals .....	45
2.11.4.	Experience and case selection .....	45
2.11.5.	Communication with technicians .....	45
<b>2.12.</b>	<b>Differences in clear aligner therapy approach between orthodontists and general dentists .....</b>	<b>45</b>
<b>2.13.</b>	<b>Clear aligners through online information .....</b>	<b>46</b>
<b>2.14.</b>	<b>Future of clear aligners.....</b>	<b>48</b>
<b>2.15.</b>	<b>Clinical cases.....</b>	<b>49</b>
2.15.1.	First clinical case .....	50
2.15.2.	Second clinical case.....	52
2.15.3.	Third clinical case.....	55
<b>III.</b>	<b>CONCLUSIONS.....</b>	<b>57</b>
<b>IV.</b>	<b>REFERENCES.....</b>	<b>59</b>



## FIGURES INDEX

<b>Figure 1:</b> Clear aligner.....	18
<b>Figure 2:</b> Attachments and precision cuts placed by ClinCheck software .....	20
<b>Figure 3:</b> Results by years of “Clear Aligners” in PubMed .....	21
<b>Figure 4:</b> A clear aligner made of PETG material.....	21
<b>Figure 5:</b> Attachments, Power Ridges and Bite Ramps .....	25
<b>Figure 6:</b> Intermaxillary elastics.....	26
<b>Figure 7:</b> Performing interproximal reduction using a flexible diamond-coated discs .	27
<b>Figure 8:</b> ClinCheck In-Face Visualization demonstrating original patient photo and updated photo .....	30
<b>Figure 9:</b> An athlete removing her clear aligner.....	39
<b>Figure 10:</b> Patient communication during clear aligner therapy .....	44
<b>Figure 11:</b> 3-D printed aligners .....	49
<b>Figure 12:</b> Walign aligners .....	49



## TABLES INDEX

<b>Table 1:</b> Advantages and disadvantages of fixed and removable retention.....	36
<b>Table 2:</b> Differences between fixed appliances and clear aligners, adapted from (Srivastava et al., 2017).....	43
<b>Table 3:</b> First clinical case description .....	50
<b>Table 4:</b> Photos of the first clinical case.....	51
<b>Table 5:</b> Second clinical case description.....	52
<b>Table 6:</b> Photos of the second clinical case .....	53
<b>Table 7:</b> Third clinical case description.....	55
<b>Table 8:</b> Photos of the third clinical case.....	56



## **INDEX OF ABBREVIATIONS**

**CA** | Clear Aligner(s)

**CAT** | Clear Aligner Therapy

**FA** | Fixed Appliance(s)

**FAT** | Fixed Appliance Therapy

**IPR** | Interproximal Reduction

**CAD** | Computer-Aided Design

**CAM** | Computer-Aided Manufacturing

**CBCT** | Cone Beam Computed Tomography

**PETG** | Polyethylene Terephthalate Glycol

**FDA** | Food and Drug Administration

**PI** | Plaque Index

**GI** | Gingival Index

**DTC** | Directly-To-Consume



## **I. INTRODUCTION**

### **1.1. Contextualization**

A clear aligner (CA) is a minimally visible mean of moving teeth without wires and brackets. It is a removable device made of medical thermoplastic material, which is inert and biocompatible. Different thermoplastic materials are used to thermoform CA, including polyvinyl chloride, polyurethane, polyethylene terephthalate, and polyethylene glycol terephthalate (Putrino et al., 2021).

Nowadays, the demand for aesthetic treatments is increasing, more people are looking for alternatives to fixed appliances (FA). CA are an aesthetic and comfortable option for orthodontic treatment that have gained immense popularity over the last decade. In recent years, CA have diversified and evolved in their characteristics in terms of material used, gingival margin design, attachments, and auxiliaries, increasing their indications and efficiency. The effectiveness, efficacy, and efficiency of treatment outcomes accomplished with CA, as well as the limitations of clear aligner therapy (CAT) have been controversial and a subject of debate among orthodontists (Zhao, 2019).

### **1.2. Research Methodology**

The research question of the study “what can we do and cannot do with clear aligners?” is elaborated according to the PICO method:

- ❖ Population: patients in need for orthodontic treatment
- ❖ Intervention: orthodontic treatment with CA
- ❖ Comparison: conventional orthodontic treatment with FA
- ❖ Outcome: effectiveness of treatment.

The search for articles answering the question was performed using the relevant related evidence based published literature in English, Portuguese and French languages between year 2000 to 2022 using the following search engines: PubMed, Google Scholar, Cochrane, and relevant books on the subject.

### **1.3. Objective**

The objective of this study is to critically appraise the efficiency and effectiveness of orthodontic treatment with CA by analysing the advantages and disadvantages, as well as the possibilities and limitations of CAT in comparison with Fixed Appliance Therapy (FAT).



## II. DEVELOPMENT

### 2.1. History of clear aligners

In the last decades, aesthetics has become one of the main motivations for seeking orthodontic treatment. Nowadays, society seeks a more beautiful and perfect appearance, being a considerable factor in self-esteem, quality of life and success of individuals. This fact motivated researchers to look for solutions that would satisfy these aesthetic needs during the process of treatment. Among the alternatives developed are aesthetic brackets, lingual brackets and plastic aligners (Moro et al., 2017).

The application of CA, contrary to what one might think, is not a recent technique, having been used for the first time in 1945, when Kesling introduced the “tooth positioning device”. This appliance was based on a single piece of transparent flexible rubber, built on a plaster model, from which a waxed “set-up” was performed. The teeth were moved over the plaster to the programmed position (Rossini et al., 2015).

This device allowed only slight adjustments to tooth position, being used with the aim of finishing treatments already started, or correcting mild relapses. Kesling predicted that certain important tooth movements could be performed with a set of positioners (Moro et al., 2017).

In 1971, Pontiz, from the same base as Kesling, created the invisible retainer, that could only produce minor movements in certain types and sizes of clinical crowns. Sheridan, 14 years later, developed the Kesling technique making it possible to perform interproximal reduction of teeth (IPR). However, this technique, like the ones previously described, only allowed minor tooth movements. It was necessary to make a new “set-up” and new impressions in most consultations, which made the treatment time-consuming and uncomfortable (Hennessy & Al-Awadhi, 2016).

A digital aligner system with promising features was created in the USA at the end of the 1990s. Named Invisalign, it was developed by two Stanford students; Kelsey Wirth and Zia Chishti who received an orthodontic treatment. He realized that his transparent retainer would be useful for the entirety of his orthodontic treatment. He believed that his clear retainer could straighten teeth without the use of metal braces. The two students founded the company in collaboration with two other colleagues from their campus, Apostolos Lerios and Brian Freyburger. They were in charge of the Computer-Aided Design (CAD) part. In a campus laboratory, a software was developed to design progressive stages of retainers to align teeth. The founders were able to market and sell

their product to the orthodontic community after receiving Food and Drug Administration (FDA) approval in 1998. Due to the owners lack of orthodontic experience, orthodontists were resistant to this radical change (Moya & Zafra, 2021).

In 1999, Align Technology® was officially launched in the United States, Santa Clara, California, as the first company to create a system exclusively based on a three-dimensional digital technology. Thus, the Invisalign® system has revolutionized plastic orthodontics (Cardoso et al., 2019).

With the development of three-dimensional digital technology, based on CAD and Computer-Aided Manufacturing (CAM) technology, it became possible to make models of each dental movement. With this evolution, there is no longer the need to make new “set-ups” and new impressions for each movement, as the entire series of models are created from a single impression. Thus, consecutive CA began to be used on a larger scale and have been extensively developed and improved (Figure 1) (Lombardo, Arreghini, et al., 2017) (Papadimitriou et al., 2018).



**Figure 1:** Clear aligner

Source : <https://welign.com/a-propos-de-nous/>

❖ **First generation (without any included auxiliary elements)**

One of the significant limitations of the first aligners introduced by Invisalign® in 1999, was the fact that they only could make minor corrections. These aligners were classified as the first generation aligners, not having any accessory devices and movements being performed only through tooth/aligner contact (Hennessy & Al-Awadhi, 2016).

The tooth movements produced by those aligners have not been thoroughly studied. Djeu et al. compared a cohort of patients with FA with their first 48 Invisalign patients in 2005. The authors assessed the outcomes of the different treatment modalities using the American Board of Orthodontics objective grading system. In two categories, root

angulation and marginal ridge alignment, Invisalign and FA showed comparable results. However, FA significantly outperformed removable ones in terms of buccolingual inclination, occlusal contacts, occlusal relationship, and overjet reduction. FAT also showed better results when treating moderate to severe malocclusions. The authors utilized an early version of Invisalign and lacked experience of treatment with CA. These two elements might have influenced treatment outcomes (Djeu et al., 2005).

#### ❖ **Second generation (placement of attachments and/or intermaxillary elastics)**

Since they were first introduced on the market, CA have evolved in an effort to offer more advantages and improve dental alignment and occlusion. With this evolution, the need to use accessories to improve tooth movement was perceived. Resin accessories began to be used to improve the retention of the aligner or buttons to facilitate the use of elastics. At this point, these aligners with resin fittings or buttons were classified as the second generation aligners (Hennessy & Al-Awadhi, 2016).

The precision of the tooth movements caused by these aligners was evaluated by Kravitz et al. In a prospective clinical study, the researchers compared the clinical outcomes of CA, aligners with attachments and aligners with IPR, with the virtual tooth movements predicted by the software. The anterior Invisalign aligners were used to correct 51 rotated canines. When compared to the predicted results, the mean accuracy of derotation realized was 35.8%. Adding to that, similar outcomes to patients who only received aligners were found in the groups with attachments and IPR (Kravitz et al., 2008).

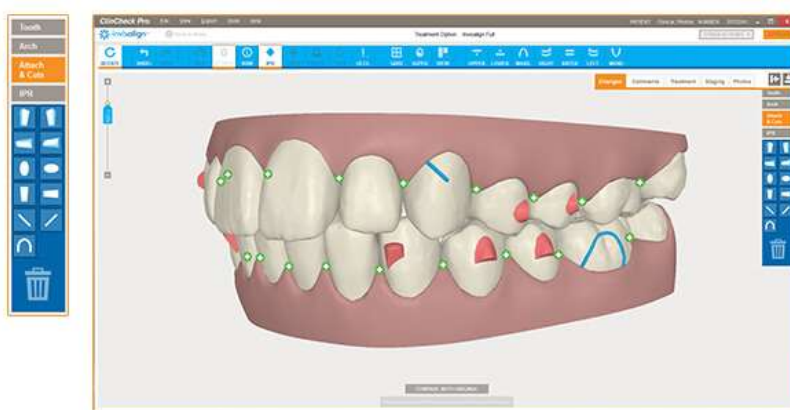
The accuracy of various tooth movements predicted in a cohort of 37 patients was then evaluated by the same researchers. Only 29.6% of extrusive movements were accomplished, while tooth movements were 41% accurate overall. These two clinical studies indicated that there was a significant difference between the virtual results and actual tooth movements. To conclude, overall accuracy did not appear to be improved by the attachments developed in the second generation of aligners (Kravitz et al., 2009).

#### ❖ **Third generation (accessories are automatically placed by the computer system)**

Attempts have been made to change the way aligner appliances deliver force in order to improve outcomes and obtain a greater control of tooth movements. Another generation of aligners was created, with certain modifications proposed: accessories and precision cuts and pressure points. In this generation, aligners are optimized by a software

that automatically places attachments (Figure 2). In the computer system, the algorithms define not only the best system of forces to carry out the necessary tooth movement, but also the best shape of the attachment to receive this system of forces. Moreover, when root torque is required, indentations are generated in the aligners (Morton et al., 2017).

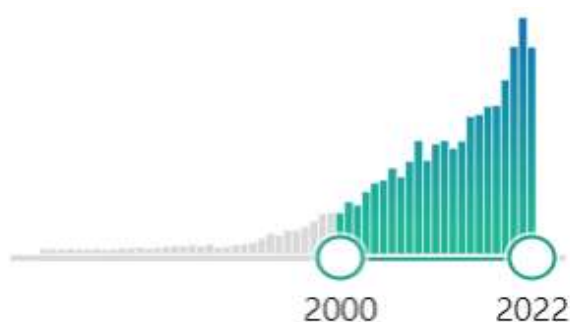
A research in 2020 aimed to provide an update on the accuracy of tooth movement with Invisalign. 38 individuals receiving Invisalign treatment were included in this prospective clinical study. Predicted values were determined by superimposing the initial and final models, and achieved values were determined by superimposing the initial ClinCheck models and the digital models from the posttreatment scans. For all tooth movements, Invisalign average accuracy was 50%. Buccal-lingual crown tips resulted in the highest overall accuracy (56%), while rotation had the lowest overall accuracy (46%). The authors concluded that the overall accuracy showed a significant improvement; yet, the strengths and weaknesses of using Invisalign to move teeth remained mostly unchanged (Haouili et al., 2020).



**Figure 2:** Attachments and precision cuts placed by ClinCheck software

Source : <http://www.invisalign-g6.com/en-XA/clincheckpro.aspx>

Over the years, research on CAT has significantly grown. The number of citations on CAT is estimated to grow consistently along with the expansion of research programs (Bruni et al., 2021). More than 4.700 entries would now (November 2022) show up in a PubMed search for "Clear Aligners", demonstrating the rise of CAT starting from only 75 results in 2000 (Figure 3):



**Figure 3:** Results by years of “Clear Aligners” in PubMed

Source: <https://pubmed.ncbi.nlm.nih.gov/?term=clear+aligners&filter=years.2000-2022>

## 2.2. Characteristics of clear aligners

### 2.2.1. Composition of aligner materials and manufacturing method

With the development of CAD/CAM technology, it became possible to use materials of thermoplastic composition in the manufacture of orthodontic aligners. Modified polyethylene terephthalate glycol (PETG) is currently the most used by manufacturers. It is a material with some hardness, good mechanical properties, formability, fatigue resistance and dimensional stability (Figure 4) (Ryu et al., 2018).



**Figure 4:** A clear aligner made of PETG material

Source: <https://www.made-in-china.com/showroom/acc22caa3aa5c5a9/product-detailFwkniyMcSIVI/China-PETG-Sheet-for-vacuum-Forming-of-Clear-Aligner-Dental-Trays.html>

There are other materials that are also used, including polypropylene, copolyester, polycarbonate, and polyurethane. These materials are widely used in orthodontic retainers, whitening trays, and appliances for temporomandibular disorders. They are known to have excellent physical, chemical and mechanical properties, such as good flexibility, chemical resistance, dimensional stability and ease of processing (Condo' et al., 2018).

As for the manufacturing method, recent research has focused on analysis of three-dimensional printed aligners, but thermoforming is still the method most commonly used to manufacture aligners (Bucci et al., 2019).

An in vitro study conducted in 2019 aimed to evaluate the cytotoxicity of different thermoplastic materials for CA on human primary gingival fibroblasts. Materials of four brands were assessed (Martina et al., 2019):

- Duran (Scheu-Dental GmbH, Iserlohn, Germany): PETG;
- Biolon (Dreve Dentamid GmbH, Unna, Germany): PETG;
- Zendura (Bay Materials LLC, Fremont, CA, USA): Polyurethane resin;
- SmartTrack (Align Technology, San Jose, CA, USA): Multilayer aromatic thermoplastic polyurethane/copolyester.

Three materials (Duran, Biolon, Zendura) were evaluated as thermoformed and non-thermoformed, while only SmartTrack was evaluated as thermoformed. After 14 days, the results showed that all materials represented a minor cytotoxic effect. The highest cytotoxicity level was achieved by Biolon, followed by Zendura, SmartTrack, and finally Duran. As for the comparison between non thermoformed and thermoformed materials (Duran, Biolon, and Zendura), the thermoformed materials showed the highest level of cytotoxicity. The authors concluded that since materials have only shown a slight level of cytotoxicity, their clinical use in manufacturing CA may be considered safe. Nevertheless, this cytotoxicity of PETG materials is increased by the thermoforming process (Martina et al., 2019).

Another study investigated the stress release properties of materials used in the manufacture of orthodontic aligners. The authors came to the conclusion that the material used has a significant impact on how well CA work. The behaviour of polymers may significantly vary as a result of stress release, which could impact the programmed teeth movement (Lombardo, Martines, et al., 2017).

### **2.2.2. Gingival margin design**

With the evolution of CA, the design of the gingival margin has become increasingly straight and extended beyond the gingival zenith. This design seems to improve adherence and thus, decreases the presence of attachments for retentive purposes. However, the influence of the gingival margin design on the effectiveness of CA is not well documented in the literature (Putrino et al., 2021).

### 2.2.3. Material thickness

CA have different thicknesses, ranging from 0.50 to 1.5 mm, which can impact their properties and performance while inducing tooth movement. The thickness of CA can be predetermined by the manufacturer or selected based on the treatment. Thinner materials may be good at providing light forces that are appropriate for tipping, while root movement or translation may require thicker material (Kohda et al., 2013) ; (Lombardo et al., 2020).

## 2.3. Attachments and auxiliary techniques

### 2.3.1. Attachments

Attachments, made of composite resin and bonded to the patient teeth, are essential in the aligner technique. They generate moment-to-force ratio components to guide orthodontic tooth movements. Each attachment has an active surface oriented to provide force in the desired direction (Valeri et al., 2022).

#### ❖ Conventional attachments

Conventional attachments have standardized shapes and sizes. They can be ovoid, rectangular, beveled or non-beveled; and they are oriented horizontally or vertically. Conventional attachments are used for retention and anchorage, to support intrusion, extrusion, or for root movement control. They are gradually activated as the treatment progresses, when the patient moves from aligner to aligner, until they reach their maximum activation (Glaser, 2017).

They can be divided into three main types (Hennessy & Al-Awadhi, 2016):

- Ellipsoid: with dimensions of 3 mm height, 2 mm width and 0.75-1 mm thickness; for incisors, canines and premolars. They are used singly to correct rotations, or in pairs for root movements. They enable more rotational control when used singly, similarly to wider brackets in FA;
- Beveled: with dimensions of 3, 4, or 5 mm width, 2 mm height and 0.25-1 mm thickness; are used for extrusion movements. Similar to fixed brackets, they have an active border that prevents slipping between the aligner and the tooth;
- Rectangular: with dimensions of 3, 4 or 5 mm width, 2 mm height and 0.5-1 mm thickness; are used when there is a need to perform large mesiodistal movements.

By enabling a greater force application span, these attachments enable teeth to be bodily moved.

#### ❖ **Optimized attachments**

Optimized attachments were developed for a variety of tooth movements. Their shapes and sizes are predetermined by the software that automatically places them. Different types of optimized attachments were created (Glaser, 2017):

- Rotation: for rotation of canines and premolars;
- Extrusion: for extrusion movements in incisors, canines and premolars; for extrusion movements on molars;
- Root control: for root control in incisors, canines and premolars;
- Optimized attachment for upper lateral incisors;
- Multiplane: for lateral incisors or molars with rotation and vertical movement, when root movement and extrusion are simultaneously required;
- Support: to support lateral incisors when there is an intrusion movement on adjacent canine or central incisors; deep bite correction; to provide support for predictable dental arch expansion in mixed dentition.

#### ❖ **Other types of attachments**

There are other types of SmartForce attachments, such as those placed on the aligners and not on the teeth as attachments. They help obtain the required movement (Moya & Zafra, 2021):

- Power Ridges:

Power Ridges are plastic bends exerting ‘push’ forces, translated to crown or root. They might be placed alone, and are not compatible with attachments (Figure 5).

- Pressure Points:

Pressure Points can be placed in combination with attachments, for example, to promote teeth rotation or intrusion.

- Precision Ramps:

Precision Ramps are usually dynamic, changing on every aligner, adapting to tooth movement. In contrast to fixed turbo bites, Precision bite ramps produce only the required tooth disocclusion (Figure 5).



➤ Precision Wings:

Precision Wings were developed for mandibular advancement features. They help in advancing the mandible on a preset basis.

➤ Divots:

The divots are small depressions that have been pre-programmed and implanted into the invisible aligners. They were developed to replace attachments and guide a variety of movements, such as rotations and minor tipping movements. Divots could also help with the aligner retention. Despite their highly promising efficacy, their impact in the literature is still insufficiently documented (Lombardo et al., 2020).



**Figure 5:** Attachments, Power Ridges and Bite Ramps

Source: [https://www.adentics.de/images/downloads/ADENTICS\\_General\\_Information\\_Aligner\\_Therapy\\_Invisalign\\_en.pdf](https://www.adentics.de/images/downloads/ADENTICS_General_Information_Aligner_Therapy_Invisalign_en.pdf)

A systematic review of the literature published in 2022 aimed to assess the differences between CA that differ in the presence of attachments or in attachment configuration. Six groups of movements were analysed (mesiodistal tipping/bodily movement; anterior buccolingual tipping/root torque; posterior buccolingual tipping/expansion; intrusion; extrusion; rotation). The study showed that attachments mostly increased the effectiveness of orthodontic treatment with CA, improving anterior root torque, rotation, and mesiodistal movement. They could also improve posterior

anchorage. Additionally, attachments seem to improve intrusion. However, the evidence is insufficient about this movement, as well as extrusion (Nucera et al., 2022).

### **2.3.2. Auxiliary techniques**

CAT requires auxiliary techniques, such as elastics, IPR, mini-screws, lingual buttons, powerchains, and temporary anchorage devices, in order to improve control of tooth movements and accomplish better treatment outcomes (Weir, 2017).

The use of these auxiliary devices have expanded the indications for CAT, especially in situations that aligners alone could not handle with predictability (Putrino et al., 2021).

The retrospective study carried out by Lombardo et al. in 2017 aimed to evaluate the predictability of orthodontic movement with CA. The researchers found that aligners could not achieve programmed movement with a certain predictability without using auxiliaries (Lombardo, Arreghini, et al., 2017).

#### **❖ Elastics:**

Orthodontic elastics are used to help achieve various biomechanics. They are attached to the aligner plastic itself, to bonded buttons on teeth, or to mini-screw anchors. Buttons bonded on the buccal surfaces of posterior teeth help create “triangle, box, or up-and-down” elastics to place teeth into the aligners and into the final occlusion. Intermaxillary elastics (Figure 6) are used to correct antero-posterior discrepancies between dental arches or to control anchorage (Bowman et al., 2015); (Lombardo et al., 2018).



**Figure 6:** Intermaxillary elastics

Source: <https://diamondbraces.com/invisalign/invisalign-rubber-bands/>

### ❖ Interproximal reduction

IPR is performed during orthodontic treatment to reduce mesiodistal tooth size (Figure 7). This technique addresses lack of space (mild and moderate crowding), Bolton tooth size discrepancy, correction of morphologic anomalies, tooth reshaping and management of gingival papilla. Several techniques are used, including air rotor stripping with fine tungsten carbide or diamond burs, handpiece or contra angle mounted diamond-coated disks, and handheld or motor-driven abrasive metal strips (Pindoria et al., 2016).



**Figure 7:** Performing interproximal reduction using a flexible diamond-coated discs

Source: <https://www.aegisdentalnetwork.com/id/2010/03/revolutionizing-interproximal-enamel-reduction>

## 2.4. Biomechanics of clear aligners

CA straighten teeth mainly by tipping movement of individual teeth or groups of teeth by about 0.15 to 0.3 mm. This alignment is achieved by a series of aligners worn for 20 to 22 hours every day and switched out every one to two weeks (Henrikson, 2020).

Tooth movements performed by CA include (El-Bialy et al., 2016):

- Pure tipping:
  - Occurs when the crown of a tooth moves in one direction, while the apex of its root moves in the opposite direction
- Controlled tipping:
  - Occurs when the crown of a tooth moves in one direction, while the apex of its root remains in its original position. It is called controlled because the

undesired effect of tooth apex movement does not occur or is less likely to occur.

➤ Translation:

In this type of tooth movement, the center of rotation would be at infinity, assuming that the crown and root move the same distance, almost without rotation.

➤ Rotation:

Pure rotation occurs when the tooth rotates around its center of resistance.

➤ Torque:

In this type of tooth movement, the root of the tooth moves in one direction while the crown remains in the same position.

➤ Intrusion and Extrusion:

This tooth movement occurs in the axial direction and the center of rotation is located at infinity. It is an axial type of translation.

A systematic review of the literature conducted by Papadimitriou et al. in 2018 aimed to evaluate the available evidence regarding the effectiveness of treatment with Invisalign system. The study included 3 RCTs, 8 prospective, and 11 retrospective studies with a moderate general level of evidence and a low to high risk of bias. The majority of the included studies assessed the accuracy of Invisalign or compared it to conventional FA (Papadimitriou et al., 2018).

The results showed that the accuracy was sufficient when related to certain malocclusions, such as overjet and anterior arch length discrepancy, or to maxillary molar distalization. However, important limitations were reported for bodily expansion of the maxillary posterior teeth, canine and premolar rotational movements, extrusion of maxillary incisors, and in overbite control. As for the comparison to FA, from studies with moderate to low risk of bias, Invisalign seemed to perform well in mild to moderate non-extraction cases, but it could not equally succeed in more difficult cases, including extraction cases. Based on the available evidence, the authors concluded that:

- While Invisalign may be able to manage mild non-extraction situations more rapidly than FA, it takes longer to treat severe cases.
- Dental arches can be safely straightened using Invisalign aligners by leveling and derotating the teeth (except for canines and premolars). Crown tipping can be easily performed.

- When it comes to the accuracy of planned movements accomplished with aligners, teeth inclinations and occlusal contacts appear to be among Invisalign limitations.
- Additional attachments could be more useful for controlling overbite, canine and premolar rotational movements, and various other types of movement, including the bodily expansion of the maxillary posterior teeth.

In 2021, a retrospective clinical study conducted by Jiang et al. aimed to evaluate the treatment efficacy of pure tipping, controlled tipping, translation, and torque movements of incisors using CA. The researchers analysed pretreatment and posttreatment Cone Beam Computed Tomography (CBCT) images obtained from 69 patients who had non-extraction orthodontic treatment with CA. The results showed that the effectiveness of incisor movement with CA varies depending on the type of intended movement. The most accurate tooth movement was pure tipping (72.48%), followed by controlled tipping and translation, whereas the least accurate was torque (35.21%). Results also showed that labial root movement was significantly more accurate than the lingual root movement (Jiang et al., 2021).

#### ❖ Principles of treatment technique with clear aligners

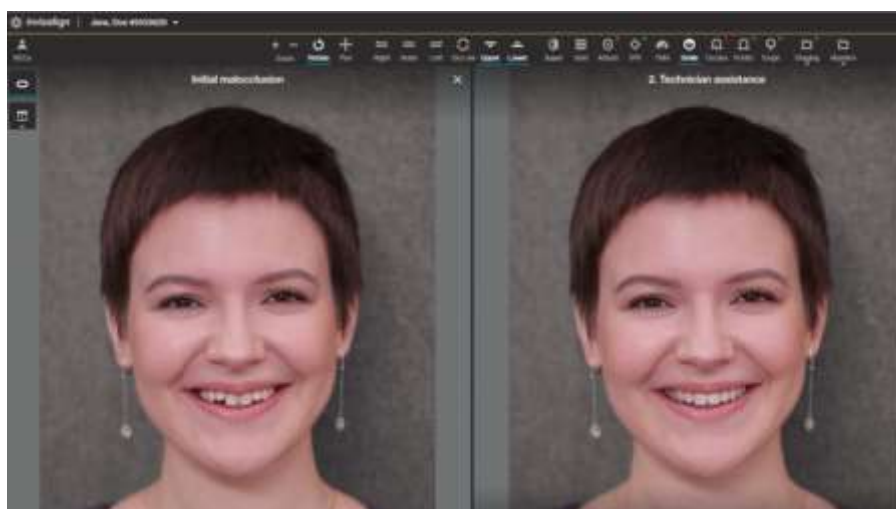
There are several important principles to know about treatment technique when performing CAT (Srivastava et al., 2017); (Glaser, 2017):

- Aligners do not pull teeth; they push:  
For the desired movement to occur, it is essential to have a pressure surface adapted to each tooth.
- Anchoring movements are required to perform efficient movements:  
Similar to FA, anchoring movements are also widely used by CA.
- For the teeth to be able to move, the existence of space in the arch is essential.
- The initial forces to which the aligners are capable correspond to 200 g. These forces gradually decrease until they reach 40 g in 48 hours.
- It is not advisable to skip the aligners sequence. The correct use of each one is important.
- Alignment therapy requires more than just aligners:  
Auxiliaries should be employed to improve the predictability of orthodontic movement (Lombardo et al., 2018).
- Overcorrections and refinements:

To improve CAT efficiency, some authors recommended the incorporation of overcorrection in the initial phase of virtual treatment planning, especially for challenging movements, particularly inclination and rotation (Palone et al., 2022).

### ❖ Virtual treatment planning

Radiographs, photographs and impressions are sent to the laboratory from the dentist. These information allow the software model to create the treatment protocol (Figure 8). The technician will move each tooth in three dimension, predict the “collisions” (2 teeth occupying the same space) and build the sequence of teeth movements leading to the correction of malocclusion. Then, the treating dentist could approve the treatment protocol and receive a series of aligners sent from the laboratory. The number of aligners depends on the case complexity ranging from ten for minor corrections, to 25 for moderate malocclusions, and could reach 40 for severe cases. Depending on the case, attachments and/or auxiliary techniques, such as elastics and IPR, could be required (Srivastava et al., 2017).



**Figure 8:** ClinCheck In-Face Visualization demonstrating original patient photo and updated photo

Source: <https://www.invisalign.com/provider/ccpro6.0>

## 2.5. Possible treatments with clear aligners

According to Srivastava et al., orthodontic treatments performed by aligners system present their main indications for cases of (Srivastava et al., 2017):

- Correction of relapses after using conventional FA;
- Closure of mild diastema and correction of mild to moderate dental crowding, both less than 5mm;
- Lower incisor extraction in cases of severe crowding;
- Tooth intrusion of 1 or 2 teeth;
- Distal movement of molars;
- Constricted arches of non-skeletal origin;
- Expansion of dental arches without excessive tipping and correction of a posterior dentoalveolar crossbite in order to improve smile aesthetics or to create space for correction of crowding;

### **2.5.1. Orthodontic treatment of growing patients**

Forty initially identified skeletal Class II patients having a mean age  $12.9 \pm 1.7$  years and receiving Invisalign treatment were included in a prospective controlled study by Ravera et al., in 2021. The study aimed to compare the dental and skeletal effects of intermaxillary elastics on the correction of mild Angle Class II division 1 malocclusion with CAT versus FAT in growing patients. The results showed that, in the short term, CAT may be useful for treating Class II growing patients with retrognathic mandibles. Moreover, therapy during the pubertal spurt seems to induce skeletal effects with an annual rate of change of 5.8 mm. In the contrary, treatment with CA during the pre-pubertal stage of growth induce dentoalveolar rather than skeletal effects (Ravera et al., 2021).

A prospective study by Lione et al. realized in 2021, included 23 patients with a mean age 9.4 years who had non-extraction orthodontic treatment with Invisalign First System CA and only attachments as auxiliaries. The objective was to evaluate the transverse maxillary arch development with CAT in growing subjects. The results analysis showed that CAT could be regarded as useful in growing patients who need to develop their maxillary arches (Lione et al., 2021).

Staderini et al., in 2022, reported two cases of anterior crossbite correction in eight-year-old children using CA with promising results. The authors approved that CAT should be thought of as a comfortable and well-tolerated treatment for young patients who have a mixed dentition and need to correct an anterior cross bite (Staderini et al., 2020).

32 patients from 7 to 11 years of age were selected for a randomized clinical trial conducted in 2022. The objective of this study was to compare the efficacy and efficiency between CA and 2 × 4 FA for correcting maxillary incisor position irregularities in the mixed dentition. The researchers found similar outcomes, in terms of posttreatment arch shapes, incisor irregularity index and treatment time, in the two groups. Thus, it was concluded that the choice of appliance should be guided by clinician and family preference, taking into account the difference of treatment cost, being much higher in case of CAT (Silva et al., 2022).

### **2.5.2. Mild to moderate malocclusions**

A systematic review of the literature published in 2020 included one randomized controlled trial and six retrospective cohort studies. Robertson et al. concluded that in cases of mild to moderate malocclusions, CA could result in clinically acceptable results that are comparable to FAT (Robertson et al., 2020).

Another study compared treatment outcomes using CA versus FA of 52 patients among teenage population (mean age was 13 years). The study demonstrated that, for mild malocclusions, treatment with CA could produce noticeably superior outcomes in terms of assessments of tooth alignment, occlusal relations and overjet (Borda et al., 2020).

In 55 patients aged from 20 to 25 years, treatment outcomes of aligner-based orthodontic treatment were evaluated in a study published in 2021. The authors found a considerable improvement in the morphological and functional characteristics of dental arches achieved by an orthodontic treatment with CA (Gvozdeva et al., 2021).

### **2.5.3. Crowding cases**

A systematic review of the literature carried out in 2020 by Kassam and Stoops, included three non-randomised and one randomised controlled trial involving 96–182 patients having a mean age between 15 and 33 years. Patients undergoing orthodontic treatment using thermoplastic removable aligners were compared to others receiving conventional fixed orthodontic appliances. According to the authors, CAT seems to be effective in treating crowding cases and class I malocclusions in extraction cases (Kassam & Stoops, 2020).



#### **2.5.4. Sagittal plan**

A systematic review of the literature, carried out in 2020, found that, in mild to moderate malocclusions, CA may provide clinically acceptable results that are comparable to FA for buccolingual inclination of the upper and lower incisors (Robertson et al., 2020).

A cephalometric analysis was performed before and after treatment of mild Class II division 1 malocclusion with CAT and FAT in 2022. With the use of Class II elastics in 49 patients, Dianiskova et al. found that the sagittal disparities are similarly corrected by both systems CAT and FAT. Additionally, CA presented a better control in the proclination of the lower incisors. That's why, in situations where a proclination of the lower incisors is undesirable, the authors concluded that CA and elastics may be a useful solution in the correction of minor Class II malocclusion (Dianiskova et al., 2022).

#### **2.5.5. Vertical plan**

In 45 patients with open bites, CAT was able to reduce and control the vertical dimension in a retrospective study by Harris et al., in 2020 (Harris et al., 2020).

Another study of the same type and published one year later, included 48 patients comparing two groups; one treated with CAT and another with FAT. The authors concluded that both systems, were successful in opening deep bites at dentoalveolar and skeletal level. However, FAT induced more obvious skeletal changes than CAT in deep bite adult patients (Henick et al., 2021).

#### **2.5.6. Transversal plan**

According to a retrospective study carried out in 2021 with a sample of 20 patients treated with CA for dentoalveolar maxillary expansion, CAT could be an acceptable substitute for conventional slow maxillary expanders in cases of mild crowding or a limited transverse maxillary (Levrini et al., 2021).

#### **2.5.7. Orthognathic surgery procedures**

A retrospective study, including a total of 33 patients undergoing complex bimaxillary-jaw orthognathic surgeries, aimed to compare treatment outcomes using CA and FA. It was demonstrated that orthognathic procedures can be successfully performed in CA patients (Kankam et al., 2019).

Prior to the orthognathic surgery, regenerative corticotomy was carried out with CA on ten adult patients (40 anterior teeth) with skeletal Class III malocclusion. The study showed that, in the pre-orthognathic decompensation period, CA with three-dimensional digital planning appears to be reliable in controlling tooth movements (Brugnami et al., 2021).

## **2.6. Limitations of clear aligner therapy**

Until more evidence-based studies are available, aligners cannot be commonly assumed as a successful alternative to FA (Hennessy & Al-Awadhi, 2016).

The limitations regarding this type of orthodontic treatment, according to Cardoso et al., include (L. G. Cardoso et al., 2019):

- Diastemas and crowding greater than 5mm;
- Space closure after premolar extraction;
- Arches that present multiple tooth loss;
- Rotation, extrusion and distalization of molars, since they are teeth with larger caliber;
- Short clinical crowns;
- Patients with periodontal disease;
- Need for patient collaboration;
- Anteroposterior skeletal discrepancies greater than 2 mm;
- Teeth that have rotations greater than 20°;
- Discrepancy between centric occlusion and centric relation;
- Anteroposterior discrepancies and overjet greater than 2 mm;
- Teeth with dental inclination greater than 45°;
- Patients with dental extrusions;
- Torque control;
- Severe overbite;
- Transverse collapse;

### **2.6.1. Final occlusion**

Many studies found that removable aligners could not always produce ideal results for the anterior-posterior position or ultimate occlusion (Kassam & Stoops, 2020) (Ke et al., 2019).

### **2.6.2. Post treatment relapse**

In the systematic review of the literature carried out in 2020 by Kassam and Stoops, after treatment, patients treated with CAT were found to be more prone to relapse than those treated with FAT (Kassam & Stoops, 2020).

Yassir et al. also confirmed in their overview of systematic reviews, published in March 2022, that, with CAT, relapse seems to be more probable (Yassir et al., 2022).

### **2.6.3. Severe cases**

Yassir et al. conducted a comprehensive literature search, overviewing a total of 18 systematic reviews published up to July 15, 2021, in order to assess the available data on the therapeutic efficacy of CAT. The results demonstrated that, in individuals with mild-to-moderate malocclusion, but not in situations of severe malocclusion, actual evidence supports the use of aligners as an alternative to FA (Yassir et al., 2022).

### **2.6.4. Tooth movement predictability**

The systematic review of the literature conducted by Robertson et al in 2020 concluded that, despite recent technological advancements, the majority of tooth movements may not be predictable enough to be achieved with a single set of trays of CA (Robertson et al., 2020).

A study conducted by Patterson et al. in 2021 aimed to find out if CA could be used to treat Class II malocclusions after the initial set of aligners in 80 adult patients. It was demonstrated that, while CA successfully move some teeth, they fail to predictably move others. In the adult population, elastics did not significantly reduce the overjet or correct Class II for an average of 7 months. Besides, an increased incidence of posterior open bite suggests that more adjustments may be required to resolve problems presented during treatment (Patterson et al., 2021).

Thirty individuals with anterior crowding under 4 mm per arch, non-extraction cases, and no modifications in the posterior relationship were included in a prospective clinical study in 2021. The study aimed to assess the accuracy of tooth movements using CA. In all six categories of tooth movement, the achieved tooth movements were much less than the planned tooth movements. 56.18 % of tooth movements with CA were accurate overall. Mesiodistal tooth movement was the most accurate (72.33 %). Intrusion was the movement that was least accurate (43.28 %). In contrast to intrusion and

extrusion, mesiodistal, labial, rotation, and lingual tooth movements were more predictable (Sachdev et al., 2021).

## 2.7. Retention post clear aligner therapy

One of the most difficult aspects of orthodontic practice is maintaining teeth in their corrected positions after active orthodontic treatment. Because of periodontal and gingival, soft tissue, occlusal, and growth factors, teeth tend to return to their pre-treatment positions. Normal dentofacial ageing could also cause changes that are highly unpredictable. Thus, retention should be adjusted in the most optimal way (Millett, 2021).

Orthodontic retention can be fixed using a bonded metallic retainer from canine to canine or from premolar to premolar. It can also be removable using a clear plastic retainer (Brezulier et al., 2016).

Advantages and disadvantages of the two types are indicated in the following table (Table 1) (Littlewood et al., 2021); (Moya & Zafra, 2021):

**Table 1:** Advantages and disadvantages of fixed and removable retention

	<b>Advantages</b>	<b>Disadvantages</b>
<b>Fixed retention</b>	<ul style="list-style-type: none"> <li>• More effective than removable one</li> <li>• Minimum patient cooperation</li> </ul>	<ul style="list-style-type: none"> <li>• Sensitive bonding protocol</li> <li>• Less hygienic</li> <li>• Risk of break or debonding</li> <li>• If the wire is broken, it may become active and produce unwanted movements</li> <li>• Usually limited to anterior teeth</li> </ul>
<b>Removable retention</b>	<ul style="list-style-type: none"> <li>• Fit properly</li> <li>• Includes all teeth</li> <li>• More hygienic than fixed retainer</li> </ul>	<ul style="list-style-type: none"> <li>• Patient compliance is required</li> <li>• Laboratory cost</li> <li>• Risk of retainer loss or break</li> <li>• Risk of discolouration</li> </ul>

## **2.8. Advantages of clear aligners**

### **2.8.1. Indications**

An example where CAT could be interestingly beneficial is treating patients with amelogenesis imperfecta and dentinogenesis imperfecta, who frequently require orthodontic therapy as a result of dental and/or skeletal issues. In contrast to FA, the use of CA with the presence of these anomalies is advantageous (Sawan, 2021).

This is due to the damaged enamel that is difficult to manage with conventional fixed braces. Also determining whether it can sustain the force used during orthodontic treatment and while removing the appliances is challenging (Chen et al., 2013).

Orthodontic therapy is also necessary for those with special needs, such as patients with Down syndrome, autism spectrum disorder, or intellectual deficiency. When compared to other patients, chairside time is increased by an average of 50%, and treatment time is extended by 25% (Antonarakis & Kiliaridis, 2021).

In children with special needs, bonding brackets is a challenging procedure to perform and their autonomy in daily hygiene is quite limited. With the use of invisible aligners, this problem is avoided, since they are removable. The negative experiences with conventional orthodontic appliances for this group of patients is the reason for switching to CAT (Carvajal Monroy, 2021).

### **2.8.2. Root resorption**

In a study published in 2020, Li et al. investigated and compared the prevalence and severity of apical root resorption of 373 roots from 70 patients treated with CA and FA. The researchers found that patients wearing CA had lower prevalence and severity of apical root resorption, as evaluated by CBCT, than patients wearing FA. This could be the result of intermittent forces induced by CA, allowing the cementum repair process. In contrast to CA, FA produce continuous orthodontic forces (Li et al., 2020).

In another retrospective study, the occurrence and severity of external apical root resorption were examined in 320 incisors from 40 Class II patients treated with aligners. Through the analysis of pretreatment and posttreatment CBCT images, the authors indicated that during CAT, the majority of incisors revealed mild to moderate resorption, and only 0.6% of them had severe resorption. The study also shed light on the risk factors for external root resorption. It was found that extraction increased the risk of root resorption, possibly as a result of the large tooth movement and reduction in overjet when

closing extraction spaces. In addition, tooth type may be involved, since maxillary incisors showed greater resorption than mandibular incisors. Root resorption was also positively related to intrusion and extrusion movements, possibly due to vertical forces that produced the greatest stress at root apex (Liu et al., 2021).

### **2.8.3. Oral health**

With CA, there is almost no risk of food retention during meals, resulting in a better hygiene and a reduced risk of occurrence of caries and gingivitis. A systematic review and meta-analysis of the literature in March 2021 confirmed that patients with aligners and no additional attachments show significantly higher levels of oral health in the short term following the start of orthodontic therapy (Oikonomou et al., 2021). This is probably a result of cleaning the oral cavity being significantly easier. In fact, toothbrushes, manual or electric, and dental floss can access all surfaces of teeth and interproximal spaces, without the interference of brackets or archwires, contrary to what occurs with fixed orthodontic appliances (Sharma et al., 2021).

A meta-analysis of the literature realized in 2018 indicated that planning treatment for adult orthodontic patients who are at risk of developing gingivitis or/and periodontitis should take CA into account. In fact, periodontal health in patients undergoing CAT was compared to that of those undergoing FAT. The authors found that CAT outperformed FAT in terms of periodontal health, including Plaque Index (PI) and Gingival Index (GI) (Q. Jiang et al., 2018).

Another longitudinal comparative study in 2022 examined clinical indicators and the microbiological alterations occurring during orthodontic treatment with FA and CA. The accompanying PI and GI -associated oral microbial communities showed that CA had better outcomes for the oral health index than FA (Shokeen et al., 2022).

Concerning white spots, a group of 244 CAT patients was compared to a group of 206 patients treated with FA. A less risk of developing white spots was found in the first group using CA. According to the authors, this could be the result of a shorter orthodontic treatment duration with CA, or a better pretreatment oral hygiene (Buschang et al., 2019).

### **2.8.4. Aesthetics**

Patients who request CA are revealed to be motivated mostly by aesthetic reasons. Given the transparency of materials used, CA are discrete, which gives them an advantage

over conventional metal brackets. This characteristic helps lessen social limitations, enabling patients to smile with greater confidence (Ke et al., 2019).

### 2.8.5. Comfort

Comparing CA to FA, the removability and small size of CA generate superior functional and psychological differences. These devices are sought for in the case of athletes since CA can act as restraints during physical activities, which could prevent traumas (Figure 9). In addition, CA cause less eating disturbance, as patients could easily remove them before eating (Weir, 2017); (Zhang et al., 2020).

Another important point, when performing FAT, it is recommended to remove metal orthodontic appliances before carrying out diagnostic tests, such as magnetic resonance imaging. In contrast to CA, FA may cause artefacts, especially if the target area is close to orthodontic appliances (Hasanin et al., 2019).



**Figure 9:** An athlete removing her clear aligner

Source : <https://www.invisalign.com/the-invisalign-difference/teen>

### 2.8.6. Perceived pain

Many studies indicated that treatment with CA is much less painful compared to treatment with fixed orthodontic appliances, especially during the initial stages of therapy, CA-treated orthodontic patients seem to experience less discomfort than FA-treated individuals (Cardoso et al., 2020) (Pereira et al., 2020) (Gao et al., 2021)(Sharma et al., 2021).

### **2.8.7. Motivation for orthodontic treatment**

Through the use of transparent aligners that show a true perception of the results, this system enables the patient to more clearly see the progress of their treatment. Moreover, the opportunity to see the final outcomes in an electronic program could enhance patient motivation and compliance (Ben Gassem, 2021).

### **2.8.8. Treatment duration and number of appointments**

Many studies found that CA could reduce treatment duration and chair time, as well as lessen the number of appointments (Zheng et al., 2017) (Ke et al., 2019) (Borda et al., 2020).

In 2021, the results of a randomized controlled trial study indicated a significant reduction in treatment duration, chairside time and finishing stage appointments. The study included 60 patients who were treated with CA for correction of non-extraction Class I crowding (Agarwal et al., 2021).

### **2.8.9. Emergencies**

With CA, emergencies seem to be rare because trays are much less susceptible to causing injuries, particularly to the mucosa or tongue, compared to FA. In addition, even when these injuries are present, they are less severe than the ones caused by fixed devices. Even when a CA is damaged or lost, it can be replaced within two weeks while the patient continues to use the previous aligner (Zheng et al., 2017).

This was confirmed when 428 orthodontic patients were questioned about orthodontic-related emergencies that they had to face during 2020 coronavirus disease. The study demonstrated that orthodontic-related emergencies, such as appliance detachment and mucosa injury, are significantly decreased when using CA. Needless to say, dentists should educate their patients about how to properly care for orthodontic appliances, in order to avoid such incidents (Gou et al., 2022).

### **2.8.10. Profitability**

Another benefit, for both dentists and patients, is the reduction of chair time to which the patient is subjected per consultation. Chair time is decreased due to aligners being already ready after pretreatment planning and to the last aligner serving as a retainer. Furthermore, less staff is required while performing CAT (Ke et al., 2019).



Adding to that, the fact that bleaching and CAT may be performed and finished simultaneously allows the practitioner to treat patients more effectively (Sword & Haywood, 2020).

## **2.9. Disadvantages of clear aligners**

### **2.9.1. Efficacy**

A systematic review with meta-analyses, in 2020, including 11 studies with a total of 887 patients, aimed to evaluate the efficacy of CA and FA for orthodontic treatment. According to the available research evidence with moderate quality, the authors concluded that aligners do not seem to be as effective as braces, the gold standard of orthodontic treatment (Papageorgiou et al., 2020).

### **2.9.2. Patient compliance**

One of the biggest disadvantages of CAT is that the success of orthodontic treatment is dependent on patient compliance. It is recommended that the patient removes aligners before eating or drinking, which may be an advantage for the patient, but a disadvantage for the clinician. The patient could use the aligner incorrectly and thus, jeopardize the success of the treatment (Sharma et al., 2021).

### **2.9.3. Masticatory muscle activity**

Patients undergoing CAT usually report muscle tenderness and produce wear facets on their aligner trays. To assess the masticatory muscle response to CA, Lou et al. recorded the electromyographic activity of masseter muscle in 17 healthy adults who were receiving CAT. The authors reported that, because of an increase in wake-time parafunctional teeth clenching, CAT is linked to a brief increase in masticatory muscle activation. Fortunately, patients without temporomandibular disorders responded well to CAT, and within two weeks, the activity of masticatory muscles returned to baseline levels (Lou et al., 2021).

### **2.9.4. Speech problems**

In a prospective clinical study in 2022, speech performance of adult patients receiving CAT and FAT was evaluated. The study demonstrated that speech was greatly

impacted by CA, and even though patients adjust to some extent, normal speech did not resume after 2 months of treatment (Fraundorf et al., 2022).

#### **2.9.5. Material deterioration and loss**

Given that a CA is a removable device that must be removed during meals, there is a high possibility that the patient could lose the aligner. Composite attachment could be lost as well, if the aligner is worn for fewer than 18 hours per day, or when aligner tray seaters are used, or in the situation of unilateral mastication (Yaosen et al., 2021).

#### **2.9.6. Treatment cost**

The cost of orthodontic treatment using CA ranges from \$3000 to \$8000 in USA, while it could be less in FAT. Several factors may determine CAT cost, such as the duration of treatment, doctors experience and dental plan/insurance. Case complexity may also affect treatment cost, which could exceed the range mentioned above (Srivastava et al., 2017).

#### **2.10. Comparison between fixed appliances and clear aligners**

In the following table, comparison between FA and CA in various parameters is presented (Table 2):

**Table 2:** Differences between fixed appliances and clear aligners, adapted from (Srivastava et al., 2017)

<b>Parameters</b>	<b>Fixed appliances</b>	<b>Clear aligners</b>
<b>Colour</b>	Metal or white	Transparent
<b>Treatment time</b>	24x7 for +- 2 years	22-24 hours/day for 6 months to +- 1 year and a half
<b>Cost</b>	\$1,800 - \$5,500	Average of \$5,000
<b>Maintenance</b>	Brush brackets and wires consistently while brushing teeth	Brushing and rinsing trays in warm water
<b>Follow up visits</b>	About every month	Change aligner trays every 2 weeks; visits every 4 to 6 weeks
<b>Retention</b>	Fixed or removable	Fixed or removable
<b>Advantages</b>	<ul style="list-style-type: none"> <li>✓ More effective in complex and severe cases</li> <li>✓ No important patient compliance needed</li> </ul>	<ul style="list-style-type: none"> <li>✓ Invisible</li> <li>✓ Removable</li> <li>✓ Comfortable</li> <li>✓ Less painful</li> <li>✓ Less emergencies</li> <li>✓ More hygienic</li> </ul>
<b>Disadvantages</b>	<ul style="list-style-type: none"> <li>❖ May induce pain or discomfort, or injuries from wires, brackets or other fixed devices</li> <li>❖ May have some tooth discoloration or breakage</li> <li>❖ May have difficulty eating sticky or hard food</li> </ul>	<ul style="list-style-type: none"> <li>❖ Requires important patient compliance</li> <li>❖ Requires extra cleaning steps</li> <li>❖ Must be removed before eating or drinking anything but water.</li> <li>❖ Must brush teeth after each meal to avoid staining and developing white spots and caries.</li> <li>❖ Risk of material deterioration or loss</li> </ul>

## **2.11. Keys to successful treatment with clear aligners**

### **2.11.1. Adequate patient selection**

As mentioned above, patient compliance is crucial for a successful treatment with CA. Early detection of non-compliant patients is possible with the aid of their results. This will facilitate prompt resolution of compliance concerns during orthodontic treatment with CA (Thirumoorthy & Gopal, 2021).

A retrospective cohort study published in 2021 found that compliance for orthodontic therapy with CA varies between males and females, males being significantly more compliant than females. Among 2644 patients, 36.0% showed full compliance, 38.3% fair compliance, and 25.7% poor compliance. Patients without previous orthodontic treatment were more compliant than those who had received one. It was also indicated that for patients with low compliance, treatment duration may be extended and treatment outcomes may be compromised (Timm et al., 2021).

### **2.11.2. Effective patient communication**

Few companies offer an orthodontist to help with treatment plan, while others prefer a digital non-human support. Different means of communication can be used, such as verbal in-office communication (Figure 10), digital and paper newsletters, or even social media. It is necessary to inform orthodontic patients about the new procedure to align teeth without braces. This communication will allay the patients concerns about the procedure, outline the entire process, and support the patient from the time they receive their treatment plan until they complete their treatment. It is important to motivate them and demonstrate at each appointment the outcomes that have been achieved as a result of using CA (Moya & Zafra, 2021).



**Figure 10:** Patient communication during clear aligner therapy

Source : <https://www.invisalign.com/the-invisalign-difference/teen>

### **2.11.3. Clear treatment goals**

Having clear goals of orthodontic treatment in all plans, transversal, sagittal and vertical, is essential to successful treatment with CA (Moya & Zafra, 2021).

### **2.11.4. Experience and case selection**

Understanding the accuracy of various tooth movements may be useful for case selection, treatment planning, and the development of CA. Good results with aligners require a competent practitioner. It is essential to understand that an orthodontic treatment, whether with CA or FA, is based on mechanics, forces, and a comprehensive treatment plan that must involve every tool in orthodontics (Glaser, 2017).

Treatments to gain familiarity with CA could include (Moya & Zafra, 2021):

- Class I < 6 mm spacing or crowding.
- Deep bite < 4 mm
- Open bite < 2,5 mm
- Class II < 4 mm
- Class III < 2 mm
- Midlines shift < 3 mm

### **2.11.5. Communication with technicians**

In order to improve treatment outcomes, communication of treatment goals and the staging of movements required for the specific malocclusion should be made carefully clear when giving instructions to the technician (Moya & Zafra, 2021).

## **2.12. Differences in clear aligner therapy approach between orthodontists and general dentists**

CAT evolution has undoubtedly pushed many practitioners to consistently alter their orthodontic approach. Nevertheless, clinicians who intend to treat their patients with CA must rely on their personal clinical experience, professional opinion, and limited published evidence-based results. CAT can be provided by both general dentists and orthodontists. However, there are some notable variations between the two groups in the application of CAT in their clinical practice, in terms of case selection, treatment plan and management (Javidi & Graham, 2015).

This was also reported in the survey conducted by Best et al. who aimed to investigate differences in CAT approach between orthodontists and general practitioners. The authors found that both groups chose to use CA to correct a variety of mild to severe malocclusions. Yet, the recommended auxiliary techniques were used in different ways. This could indicate that the two groups of dentists had different treatment objectives. Overall, orthodontic specialists reported having considerably more experience with Invisalign than general dentists (Best et al., 2017).

Another study aimed to evaluate the perceptions of orthodontic case complexity among orthodontists, general dentists, orthodontic residents, and dental students and to compare their perceptions with the American Board of Orthodontics Discrepancy Index. Through a Web-based survey, orthodontists and orthodontic residents seemed to be more competent in evaluating the cases complexity. The study suggests that the capacity to assess case complexity is influenced by additional orthodontic education and training (Heath et al., 2017).

This can be explained by the findings of an online survey conducted in 2019 by Fabrizia d'Apuzzo et al. In the survey, general dentists reported learning more about CA through private courses and less via academic seminars, congress presentations, and books or papers. In contrast to general dentists, orthodontists, following their postgraduate program, are more connected to the academic environment. As for case selection, Class I spacing and Class I with crowding were the types of malocclusion that both orthodontists and general dentists mostly selected. The two groups reported feeling more confident when treating these malocclusions (d'Apuzzo et al., 2019).

### **2.13. Clear aligners through online information**

In recent years, the internet has grown in popularity as a resource for healthcare-related information, being a platform that is simple to use. According to the National Health Interview survey, 74% of adults in the USA use the internet, and 61% of them use it to search for medical information. Moreover, internet-based healthcare information is the second most popular source of patient information in the USA, after recommendations from doctors (Cohen & Stussman, 2010).

Similar to other healthcare topics, there is more information on orthodontics online, and every day, more people use the internet for various orthodontic treatment-related purposes. The patient compliance and adherence to therapy, as well as their

communication and trust with their doctor, may all be impacted by the validity and quality of the information they find online (Zhang et al., 2020).

#### ❖ On websites

A study published in 2021 aimed to assess the information related to CAT that was available on the internet, in terms of its readability, quality, and content. 111 websites were evaluated. It was revealed that English-language websites about CAT provided low-quality, hard-to-read content. It was found that professional organizations performed the best. The data quality reported by multifunctional dentistry clinics and orthodontists was quite similar. In order to reach and persuade more people, aligner companies employed their content as a productive marketing technique. The authors suggested that dentists who offer CAT could help prospective patients benefit more from their websites. Clinicians could make CAT decision-making easier if they improve their online written information. In conclusion, for potential aligner patients, websites presenting high-quality information and evidence-based data with improved readability are required (Alpaydın et al., 2021).

A similar previous study conducted by Meade & Dreyer in 2020 evaluated 49 websites and led to a comparable conclusion. The CAT-related websites content has poor information quality and is complicated to read. Adding to that, websites authors should think about employing quality of information instruments and readability tools, in order to give evidence-based and simply written information on CAT to potential patients (Meade & Dreyer, 2020).

The same authors carried out another online research study about manufacturers of aligners that make use of directly-to-consumers (DTC) marketing, instead of orthodontists or general dentists, who have often been responsible for providing orthodontic treatment. The authors selected 21 websites that provide DTC aligners. These websites were evaluated for readability, the quality of the material offered, and compared to the website standards set by the American Medical Association. They found that the readability scores of the text matched a maturity age of 13–15 years, and more than half of the websites provided extra video material. Assessment revealed that although the majority of sites were up to date, they lacked crucial details regarding authorship, cited sources, and conflicts of interest. Overall, it was determined that the information quality was poor. Besides, less than 25% of the websites' content mentions the need for long-term retention, and only one third of them state that good dental health is crucial.

Therefore, based only on the data found on the websites, it seems likely that the patient's consent for DTC aligner treatment is illegitimate (Meade & Dreyer, 2021).

#### ❖ **On social media**

In the same way, social media platforms have made it possible for information to be shared instantly, which has been made possible by the internet huge impact on how the world communicates. Individuals and organizations have used this for the distribution and sharing of private, commercial, and general information. Additionally, social media platforms have been embraced by the healthcare industries to disseminate information about medical conditions and services (Kravitz & Jay Bowman, 2016).

Social media platforms also make it possible for patients to share their experiences concerning health issues, which may help others by informing them. However, the internet is an uncontrolled space where false, misleading, or erroneous content can be posted and disseminated. This could result in disappointment and damage if people behave based on false information (Nelson et al., 2015).

According to studies, the quality of dental and orthodontic information available on social media platforms like Instagram, Twitter, TikTok, and YouTube is generally poor or moderate (Graf et al., 2020); (Maurice J. Meade et al., 2020).

Regarding CAT, an online research evaluated the information, reliability, and quality of 100 YouTube videos, revealed that videos were of average quality, but overall, information was of low reliability with insufficient content (Ustdal & Guney, 2020).

The same results showed up with a similar research on TikTok platform, where the majority of users (almost 60%) are between the ages of 10 and 29, which is also the age range for most orthodontic patients. Needless to say, orthodontic professionals must guide patients to reliable and high-quality resources (Maurice J. Meade et al., 2022).

#### **2.14. Future of clear aligners**

Technology is advancing so rapidly that radical changes are experienced in society. In 2001, there were few techniques available to treat mildly crowded Class I malocclusions with CA. However, a few years later, extraction cases, Class II malocclusions, and open bites began to be selected for CAT, and were treated more successfully over time (Moya & Zafra, 2021).



Two main factors contributed to this evolution: first, the continuous investment that manufacturers make in advancements; and second, the enormous amount of work and effort that many orthodontic researchers have made to comprehend and explain CA biomechanics. Because the results seem to be growing better, the perception of using aligners as a successful orthodontic procedure is therefore improving (Moya & Zafra, 2021).

Although the future of CA is uncertain, it is likely that a lot of attention will be paid to the following (Tartaglia et al., 2021):

- In-practice aligners due to the development of 3-D printing (Figure 11);
- CBCT use with treatment planning software;
- Growing numbers of laboratories and aligner companies;
- Lower prices.



**Figure 11:** 3-D printed aligners

Source: <https://deltaface.com/fr/impression-directe-aligners/>

### 2.15. Clinical cases

Several companies have been developed after Invisalign was introduced, such as “Welign”, recently founded by a Tunisian orthodontist in 2021 (Figure 12).



**Figure 12:** Welign aligners

Source: <https://www.facebook.com/welignaligner/photos/a.194219872119468/229615421913246/>

Three patients were treated using Welign aligners, performed by Dr. Rochdi Gargouri, are presented in this paper (with permission).
















### 2.15.1. First clinical case

Case description is illustrated in Table 3 and photos in Table 4.

**Table 3:** First clinical case description

<b>Patient Gender &amp; Age</b>	Male, 35 years old
<b>Reason for consultation</b>	“Straighten my front teeth”
<b>Malocclusion</b>	<ul style="list-style-type: none"> <li>❖ Increased overjet</li> <li>❖ Upper and Lower Anterior crowding</li> <li>❖ Lateral crossbite in the right side</li> </ul>
<b>Treatment duration</b>	10 months (from 08/04/2021 to 16/02/2022)
<b>Treatment outcomes</b>	<ul style="list-style-type: none"> <li>✓ Correction of overjet</li> <li>✓ Teeth alignment</li> <li>✓ Smile improvement</li> <li>✓ Correction of lateral crossbite</li> </ul> <p>(Posterior disocclusion in both sides was present at the end of treatment. This common side effect of CAT is caused by interocclusal plastic material of aligners that could induce transitory molar intrusion (Cogollos et al., 2022). In this clinical case, disocclusion was corrected spontaneously one week after the end of treatment)</p>
<b>Retention</b>	Bonded lingual retention from canine to canine

**Table 4:** Photos of the first clinical case

	Right side	Front	Left side	Upper jaw	Lower jaw
Before CAT					
During CAT					
After CAT					
Smile improvement					

### 2.15.2. Second clinical case

Case description is illustrated in Table 5 and photos in Table 6.

**Table 5:** Second clinical case description

<b>Patient Gender &amp; Age</b>	Male, 36 years old
<b>Reason for consultation</b>	“Antero-inferior crowding”
<b>Malocclusion</b>	<ul style="list-style-type: none"> <li>❖ Deepbite</li> <li>❖ Mild dental Class III</li> <li>❖ Upper and Lower Anterior crowding</li> </ul>
<b>Treatment duration</b>	10 months (from 18/05/2021 to 15/03/2022)
<b>Treatment outcomes</b>	<ul style="list-style-type: none"> <li>✓ Correction of deepbite</li> <li>✓ Teeth alignment</li> <li>✓ Smile improvement</li> </ul>
<b>Retention</b>	Bonded lingual retention from canine to canine

**Table 6:** Photos of the second clinical case

	Right side	Front	Left side	Upper jaw	Lower jaw
Before CAT					
During CAT					
After CAT					

<b>3-D treatment plan</b>	
<b>Smile improvement</b>	

### 2.15.3. Third clinical case

Case description is illustrated in Table 7 and photos in Table 8.

**Table 7:** Third clinical case description

<b>Patient Gender &amp; Age</b>	Female, 35 years old
<b>Reason for consultation</b>	“Improve my smile”
<b>Malocclusion</b>	❖ Upper and Lower Anterior crowding
<b>Treatment duration</b>	15 months (from 08/02/2020 to 22/05/2021)
<b>Treatment outcomes</b>	✓ Teeth alignment ✓ Smile improvement
<b>Retention</b>	Bonded lingual retention from canine to canine

**Table 8:** Photos of the third clinical case

	<b>Right side</b>	<b>Front</b>	<b>Left side</b>	<b>Upper jaw</b>	<b>Lower jaw</b>
<b>Before CAT</b>					
<b>During CAT</b>					
<b>After CAT</b>					
<b>Smile improvement</b>					



### **III. CONCLUSIONS**

Over the last decades, the orthodontic universe has evolved significantly with the innovation of new techniques and materials, such as clear aligners. That said, it is essential to compare them to conventional fixed appliances in several aspects, in order to guide clinicians in offering the best possible treatment to their patients.

Clear aligners themselves have evolved over the years, in terms of their characteristics, attachments and auxiliary techniques. The introduction of improved software, new aligner materials, and additional auxiliary devices has enhanced their effectiveness and increased their indications.

Recent research has demonstrated that clear aligners could be an important option for correcting mild to moderate malocclusions in adults and in growing patients, but still less effective and predictable than fixed appliances in cases of severe malocclusions. Final occlusion and post treatment relapse also seem to be among clear aligner limitations.

Despite all limitations, clear aligners appear to have several advantages over fixed appliances. Aligner systems offer more comfort, aesthetics and a better oral health. Patient compliance is, though, essential for treatment success.

In order to improve treatment outcomes during clear aligner therapy, good attention should be paid to patient selection, case complexity, treatment planning, clinician experience, and regular follow-up visits.

In conclusion, clear aligners have been shown to be effective in mild to moderate malocclusion cases offering various advantages. However, they should not be considered a substitute for conventional fixed appliances, but an interesting alternative for both orthodontists and patients in particular cases.

Currently, there are no evidence-based clinical guidelines for clear aligner therapy. More studies of high quality level are still required to draw firm conclusions about the efficiency and effectiveness of orthodontic treatments performed with clear aligners.



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