

Invisalign®—15 years later, has it become a real alternative to fixed appliances?

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ABSTRACT

After 15 years of existence in France, Invisalign® has become a credible alternative to treatment with attachments. This article aims to review the latest developments made by Invisalign® and the results achieved at the clinical level. In our review, which includes clinical case photographs, we explore the possibilities of the system, including expected results, limitations, and associated precautions.

KEY WORDS

Invisalign®, ClinCheck Aligners, evaluation tooth movements, unwanted movements

INTRODUCTION

One of the constants of the evolution of orthodontic devices is the search for an esthetic device which, in patient language, translates to an "unseen device."

This request for discretion occurred initially with the appearance of ceramic brackets and then lingual orthodontic devices. Another track emerged 15 years ago when thermoformed splints or aligners were used, dental displacement was no longer being performed by brackets and arches but by the successive change facilitated by transparent thermoformed splints or aligners.

If the esthetic criteria and the notion of comfort^{5,6,7} have been major arguments in the use of aligners to the detriment of the limitations of the technique, the evolution

of materials and the contribution of digital technologies have revived the use of this type of « plastic » orthodontics, particularly with Invisalign being developed by Align Technology (Santa Clara, California) in 1999 and from 2001 in France.

In the study on Invisalign, we find two distinct parts that are key to system and the control of which is crucial to the success of our treatments:

- The treatment tool, the alignment splint, and aligners are responsible for dental displacement
- The tool to be decided on is the ClinCheck, a proprietary software application that visualizes the stages of treatment until the final result and this

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is achieved by the 3D modeling of the dental movements. We will intervene at this level to confirm or refuse the proposed treatment.

I shall make my point with the aid of clinical illustrations, after 15 years of using the system and having treated

>1000 cases. I shall address the latest developments in this technique. I shall also expose its limits and discuss how they should be pushed so that aligner treatment becomes a credible alternative to multiattachment treatments.

ALIGNERS: LIMITS AND TREATMENT POSSIBILITIES

The efficiency of the aligner technique has long been the subject of many controversies^{1,4,6}. However, clinical cases have been numerous and the interest shown by practitioners has been high, as evidenced by the success of aligner sessions at Orthodontics Days. This, along with the evolution of the technique, has made the system more credible to the extent that it is now considered an acceptable alternative to multiattachment therapy. Thus, after having reviewed the litera-

ture, it is interesting to note that some studies have shown that the forces and movements generated by the aligners are similar to the values generally stated in the literature^{9,10}.

If experience plays an important role in mastering the technique of aligners, a certain number of rules will enable us to transform our scheduled treatment plans programmed on ClinCheck into actual clinical results, while adhering to the standards of orthodontic treatment.

INTRODUCTION TO ALIGNER TREATMENT

Patient Selection

The key to success is closely linked to the cooperation of our patients. The efficiency of the aligners is only visible if worn for >22 hours per day.

Invisalign® offers us, in its teen product range, wear-compliance indicators designed for use on young patients treated with the Invisalign® teen system®. These allow us to ensure that the aligners are worn as prescribed. Some practitioners do not hesitate to implement it when treating adults whose long-term cooperation is dubious. Attention should also be paid to adolescents,

who are very sensitive to the effects of fashion and new technologies, and they may forget the rigors related to any orthodontic treatment (Fig. 1).



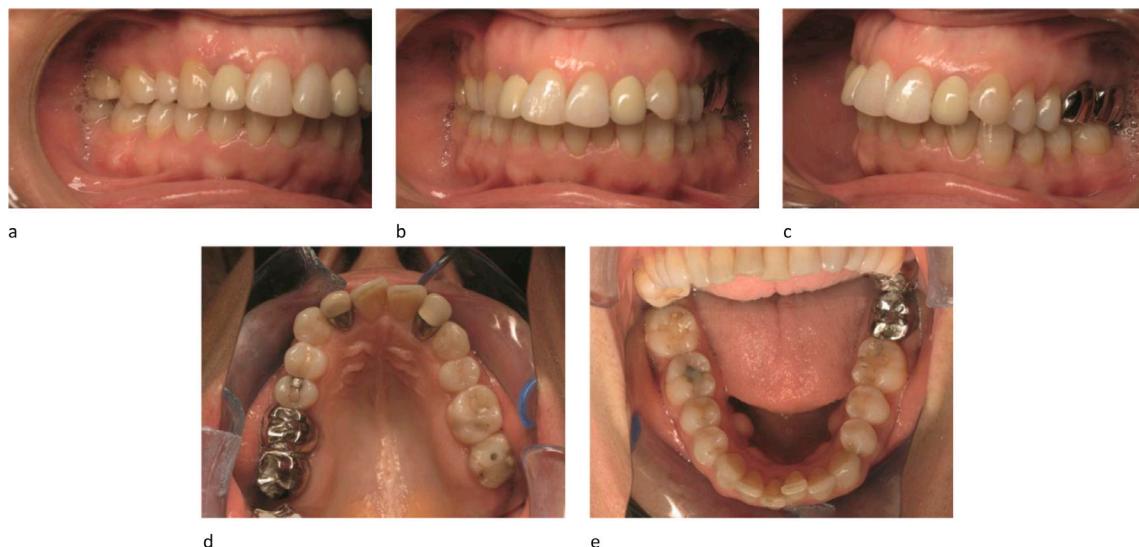
*Figure 1
Wear-compliance indicator for Invisalign treatment.*

Duration of treatment

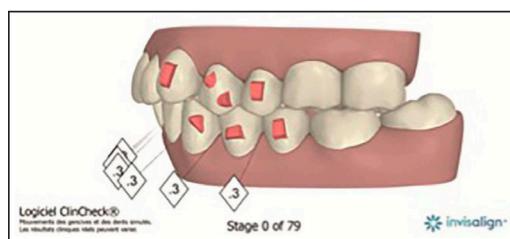
To manage the treatment more effectively, I try not to exceed a duration that corresponds to approximately 50 aligners, in other words, 24 months of treatment.

To this end, a specific, precise, and meticulous study of ClinCheck will play a key role.

Clinical case: the case of a 45-year-old patient with right asymmetrical class-II malocclusion and left canine class I (24 extracted), along with mandibular incisal overcrowding and a deviation of the incisal midlines (Fig. 2a, b, c, d, e).



*Figure 2a, b, c, d, e
Before treatment.*



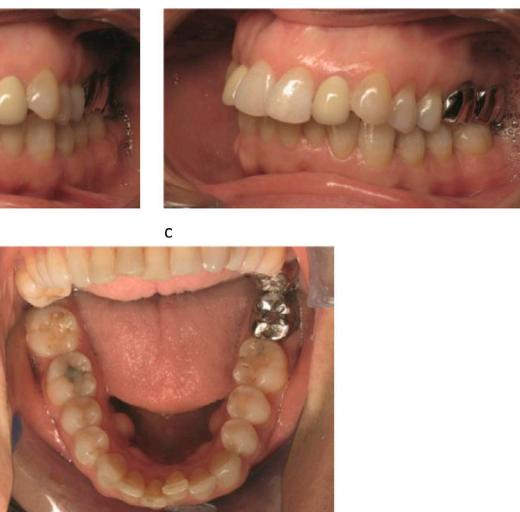
*Figure 3
ClinCheck.*

Two options were proposed to correct the class-II malocclusion:

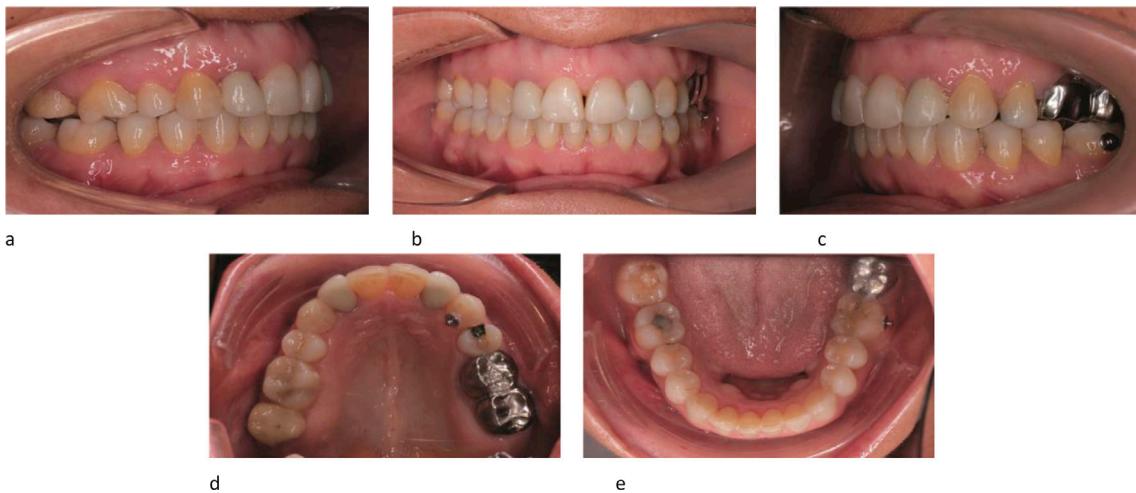
First option: correction by a class-II sequential distalization; 79 aligners were proposed for an estimated treatment duration of 3 years.

Second option: extraction of premolar 24 and conservation of the molar class II: 40 aligners for an estimated duration of 1.5 years (Figs. 4, 5).

Studying the clinical situation beforehand via ClinCheck has allowed the user, thanks to the different scenarios proposed, to have a clear appreciation of the treatment and to find the best treatment solution that would offer the best results and shortest delays.



*Figure 4
(Other option).*



*Figure 5
End of treatment.*

LIMITS OF ALIGNER TREATMENTS

Conventionally, it was believed that aligner treatment was only limited to cases of extraction and essentially

molar mesialization, severe rotations, axes corrections, and severe vertical anomalies⁶.

Severe Rotations



*Figure 6
Start of treatment.*



*Figure 7
End of treatment with persistence of canine rotation.*

Translation Movements

Example: case of closure of the maxillary incisal diastema (Figs. 8, 9).



Figure 8
Start of treatment.



Figure 9
End of treatment without control and axial version of 21.

Severe vertical anomalies: infraocclusion, supraocclusion

- Infraocclusions

Example: closure of infraocclusion by incisal extrusion (Figs. 10, 11).



Figure 10
Start of treatment.



Figure 11
End of treatment with residual anterior infraocclusion.

- Complete supraocclusion or open bites (Figs. 12, 13, 14)

Only one part of the planned intrusion was performed according to the ClinCheck treatment plan.



Figure 12
Start of treatment.



Figure 13
End of treatment.

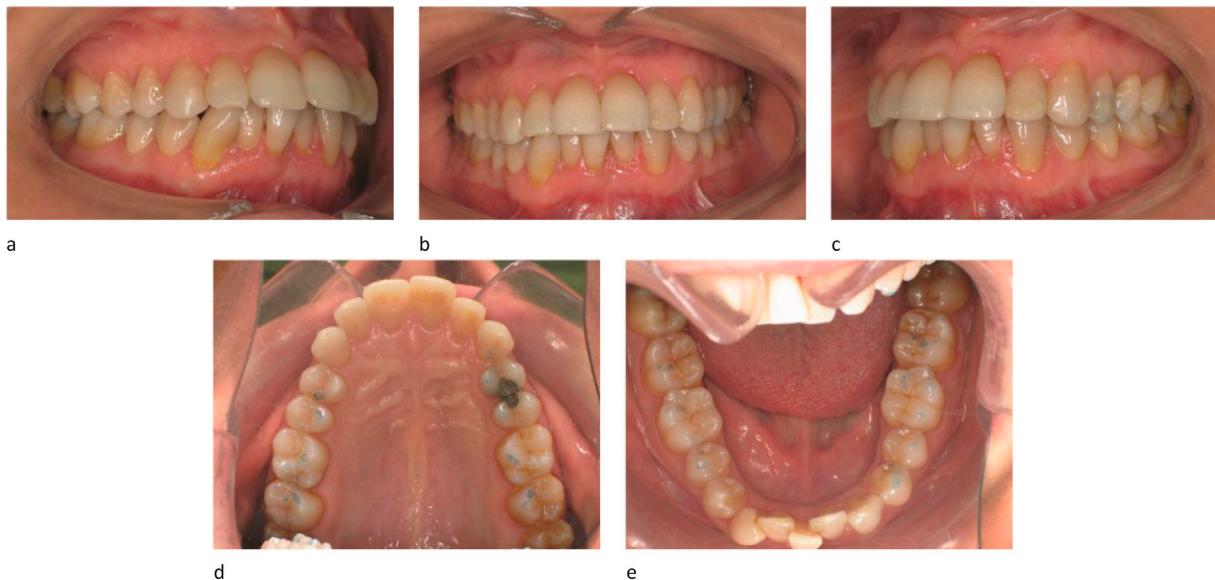


Figure 14
Predicted result from ClinCheck.

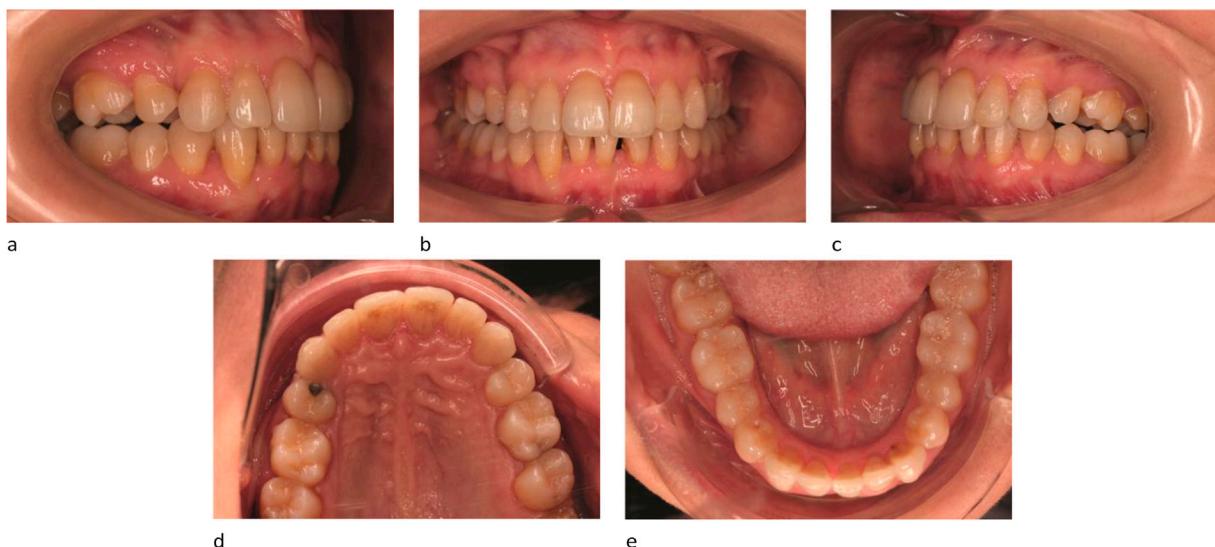
Extractions:

Example of a case of monomaxillary extraction of the first premolars 14 and 24 (Figs. 15a, b, c, d, e; 16a, b, c, d, e).

The closure of the extraction spaces is translated by a version of the posterior maxillary sectors during molar mesialization.



*Figure 15a, b, c, d, e
Start of treatment.*



*Figure 16a, b, c, d, e
End of treatment.*

Transverse corrections

Transverse insufficiencies: posterior cross-articulation. The level of force delivered by the aligners remains too low to correct an inverted joint. Only

the combined use of intermaxillary cross-traction will allow correction of the posterior joint.

Example of a treated case: (Figs. 17a, b, c; 18a, b, c).



*Figure 17a, b, c
Start of treatment.*



*Figure 18a, b, c
End of treatment.*

Confounding Movements

Posterior Inocclusion

Temporary posterior inocclusions may occur depending on the aligner thickness. We must, however, be vig-

ilant for the establishment of a dysfunction with lateral lingual interposition, which can maintain the gap and prevent its correction.

Example 1: A case of incisal diastema (Figs. 19a, b, c; 20a, b, c).



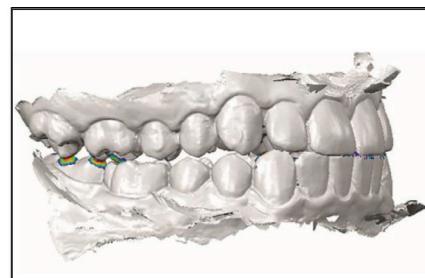
*Figure 19a, b, c
Start of treatment.*



*Figure 20a, b, c
End of the first phase of treatment before taking new impressions for orthodontic finishing.*

Example 2: Appearance of a posterior inoclusion, the optical impression shows the presence of premature contacts at the second molars. The etiology of this posterior infraocclusion is related to the absence of an "eruption tab," which creates a supraeruption of the terminal molar which is not treated by the aligner (Fig. 21a, b).

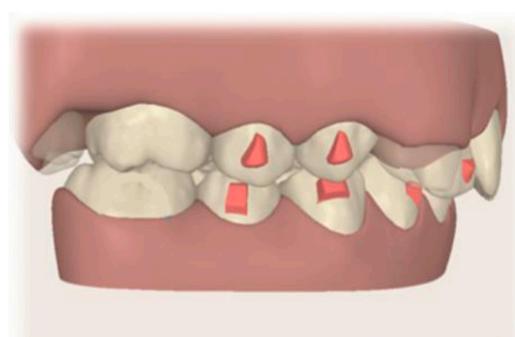
Prolongation of the aligner should be provided at a distance from the first molars, which will limit the eruption of the terminal molar not treated by the aligner (Invisalign® teen functionality; Figs. 22a, b).



*Figure 21a, b
Appearance of the lateral infraocclusion in the intraoperative view and on the digital impression.*



*Figure 22a
Aligner with eruption tab.*



*Figure 22b
ClinCheck.*

"Avoidance" Mechanisms

Example: clinical case of supraocclusion.

Invisalign® software introduced precision occlusion ramps, and new alignment features were introduced with Invisalign® G5. They act as retroincisal



*Figure 23
Before treatment.*

stops which help to correct the supraocclusion (Figs. 23, 24).

In some cases, it appears as though the mandible has an avoidance mechanism which is wedged behind the incisal "stops," thus accentuating the overhang (with the kind permission of Dr. G. Altounian; Fig. 25).



Figure 24



*Figure 25
Avoidance mechanism.*



IMPROVING THE PREDICTABILITY OF THE DENTAL DISPLACEMENTS

Knowing the limitations of the system (the removable device only affects version movements) we will implement dental movements and ensure their eligibility for treatment by alignments, according to the objectives of treatment.

Our approach will be to best match the virtual result provided by the 3D representation of the ClinCheck treatment plan with the reality of the clinical outcome.

We will be assisted in this by new developments to the Invisalign® system

(as we aim to improve the feasibility of the projected dental displacements by aligners). Moreover, by adapting our mode of reflection, we shall consider the clinical cases using an approach of anticipation and foresight where the clinical experience of the practitioners is omnipresent.

The technological evolution

Historically, the technique began with simple aligners with nonspecific attachments, and was most often relatable in terms of the clinical experience of the practitioners.

Invisalign®'s continuous innovations since 2005, including the Smart Force features and attachments, the Smart Stage technology, and the evolution of materials with Smart Track, have all been developed with the aim of obtaining a more precise control of the orthodontic movements.

Smart Track Material

Dr. Tim Wheeler's study at AAO in 2014 presents the effects of aligner materials on dental movements. The study conducted shows that the aligners benefiting from the Smart Track technology obtain a greater dental displacement, of the order of 57%, with a shorter delay than with the EX 30 (former material used in the design of the aligners).

Smart Force Features

These can be attachments with adapted geometry or accessories which are intended to improve the control of certain dental displacements, which are more difficult to attain with the aligners alone.

What type of results?

A study by Invisalign® quantified the benefits of the latest innovations. This includes >100,000 treated cases where

2010	Mai 2011	Nov 2011	2013	2014	2015
ECP	Invisalign G3	Invisalign G4	SmartTrack Invisalign G4E	Invisalign G5	Invisalign G6
<ul style="list-style-type: none"> Optimized Attachments pour l'égression et la rotation 	<ul style="list-style-type: none"> Fonctionnalité Power Ridge® améliorée pour le contrôle du torque radiculo-lingual Optimized Attachments améliorés 	<ul style="list-style-type: none"> Egression Multi-Dents pour les bénacées antérieures Fonctionnalité de Mouvement Multi-Plan pour le contrôle des latérales Optimized Attachments pour le contrôle de la version coronaire mésio-distale 			
				<ul style="list-style-type: none"> Contrôle des mouvements dentaires amélioré 	<ul style="list-style-type: none"> Fonctionnalités dédiées au traitement des supraclussions Fonctionnalités dédiées aux traitements avec extraction de première prémolaire

Table
The technological evolution.

re-evaluation impressions were used, half of which have benefited from the latest Invisalign® developments (Smart Force features and SmartTrack material).

The results show a significant improvement in the predictability of dental displacements, ranging from 30% in the case of canine extrusions with >500% increase in the torque

movements of the upper incisors benefiting from the new features.

Contribution of the new features from Invisalign, particularly the optimized attachments and clinical results.

Example 1: On the rotations of the canine premolars (case treated; Figs. 26, 27, 28, 29).

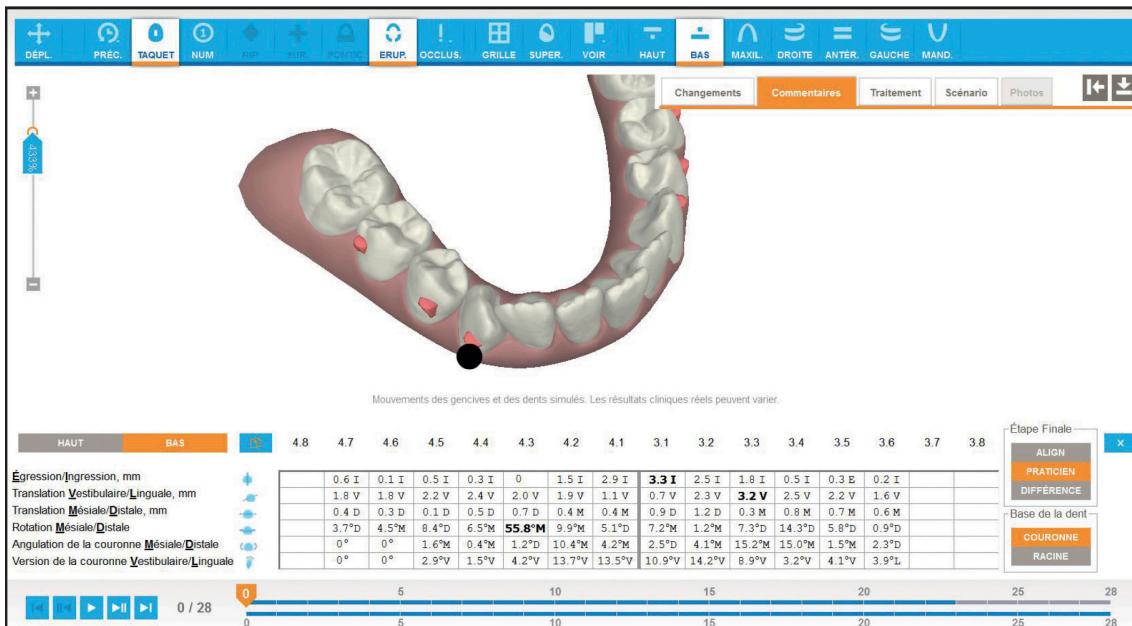


Figure 26

ClinCheck screen shot with a visualization of the degree of difficulty of the displacements (the rotation of 43° is shown as a black circle on the diagram, and a “programmed” degree of rotation of 55° is shown in the table in bold font.)

- Example 1



Figures 27, 28, 29
Before treatment, during correction, and at the end of treatment.

Example 2: Translational movements of the incisors, canines, and premolars.

Midline deviations with ectopic right maxillary canine (Figs. 30a, b, c; 31a, b, c; 32; 33a, b).

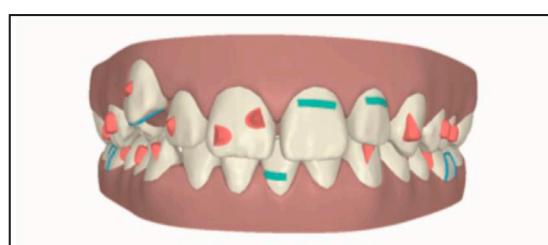
- Example 2



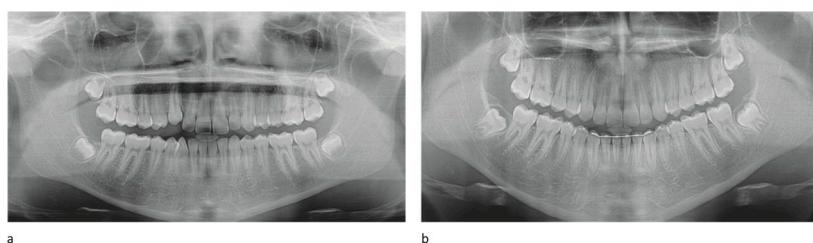
*Figure 30a, b, c
Start of treatment.*



*Figure 31a, b, c
End of treatment.*



*Figure 32
Screen shot from ClinCheck with positioning of the root control attachment.*



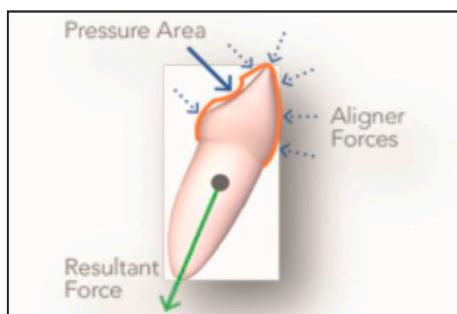
*Figure 33a, b
Panoramic radiographs at the start of treatment.*

Anterior intrusion movements (Fig. 34). Diagram of the G5 features specific to treating supraocclusions (Figs. 37, 38).

Knowing the limits of the system

The mechanical design of dental displacements with Invisalign® is no

different from other therapeutic modalities. However, it has its own characteristics of anchoring and controlling the moving teeth.



*Figure 34
Pressure zone.*



*Figure 36
Precision bite ramp.*



*Figure 35
Deep bite attachment.*



Figure 37



Figure 38

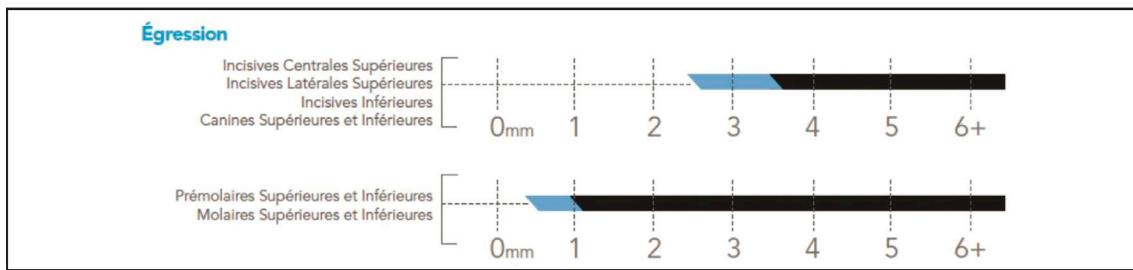


Figure 39
Evaluation of the displacements.

Feasibility study of the dental displacements

Developed by Invisalign® and specific to the aligner technique, it provides information on the most important dental movements in the ClinCheck treatment plan as well as the level of experience required to complete the treatment.

This evaluation applies to movements of extrusion, rotation, root movement, and anteroposterior corrections seen in the ClinCheck treatment plan.

This evaluation does not use cephalometric measurements or dental overcrowding. Strictly speaking, it provides no information on the difficulty of the case such as that found in the difficulty index provided by Merrifield with the following guidelines:

- *Description of intervals*
- Intervals applicable to the categories of dental movements.
- Color-coded dental movements: the color that classifies the difficulty of rotations, extrusions, root movements, and anteroposterior corrections:
 - White: No specific difficulty
 - Blue: Auxiliary techniques can sometimes be used and require careful monitoring
 - Black: Auxiliary techniques often used, very careful follow-up.

Example of extrusion movement (Fig. 39).

The table indicates >1 mm for premolars and molars and 2.5 mm for the incisors and canines; these represent the values for which dental displacement by aligner alone is not very predictable and may require auxiliary techniques.

This color guide is a guide and can be found in the "Assessment of dental displacement" form. It is given as an indication and will help us to plan our treatment and to adjust our objectives as best as possible.

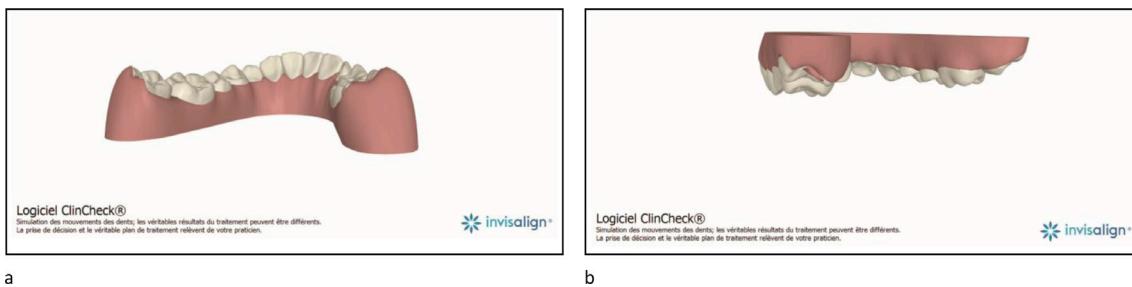
Pushing the limits of the system

Anticipating dental displacements

Depending on the crown anatomy, the contact surface of the aligner with the dental crown will determine the efficiency of the aligner, and thus the predictability of the displacement.

This contact surface is directly linked to the attachment of the clinical crown using splints.

In teens, the clinical crowns have not sufficiently evolved. Thus, to adapt to their needs, the cleats, which improve the retention of the aligner, are important (Fig. 40a, b).



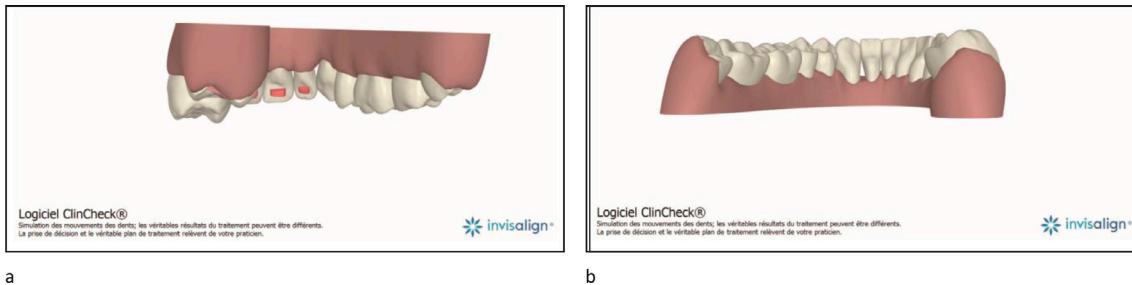
*Figure 40a, b
Low crown heights in adolescents.*

On the contrary, when treating an adult with increased crown height, or problems with recession, it would be wise to consider cutting the aligners as close to the occlusal plane as possible, or even to decrease the number of cleats or not to stick them all according to the difficulty associated with removing the aligner (Fig. 41a, b).

Depending on the initial dental position

A pretreatment analysis of the initial situation is necessary when evaluating the difficulty of aligner treatments. Indeed, these are removable devices for which the preferred movements are versions.

EXAMPLE 1. A class-III case treated with the extraction of a mandibular incisor (Figs. 42, 43).



*Figure 41a, b
Gingival recession, elongation of the clinical crown*



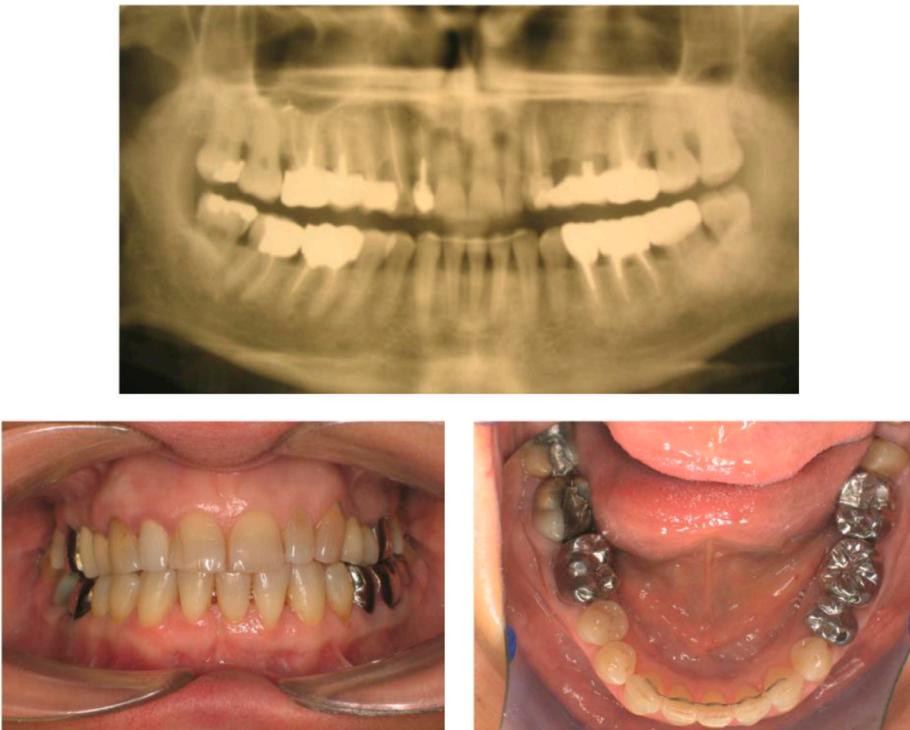
*Figure 42
Before treatment.*



Figure 43
After treatment.



Figure 44
Before treatment.



*Figure 45
After treatment.*

The results are not in line with the therapeutic predictions. The version movement at the extraction site causes the appearance of an unsightly triangular gap.

Example 2: Extraction of 41 (Figs. 44, 45).

This result can be explained by the version movement caused by the

Example 3: cross-joint 13/43 (Figs. 46a, b, c; 47a, b, c).

The coronopalatal version of the canine is a favorable factor here. Coronovestibular



*Figure 46a, b, c
Start of treatment.*



a

b

c

*Figure 47a, b, c
End of treatment.*

positioning would modify the treatment plan with the use of accessories, cleats, and the need for re-evaluative impressions.

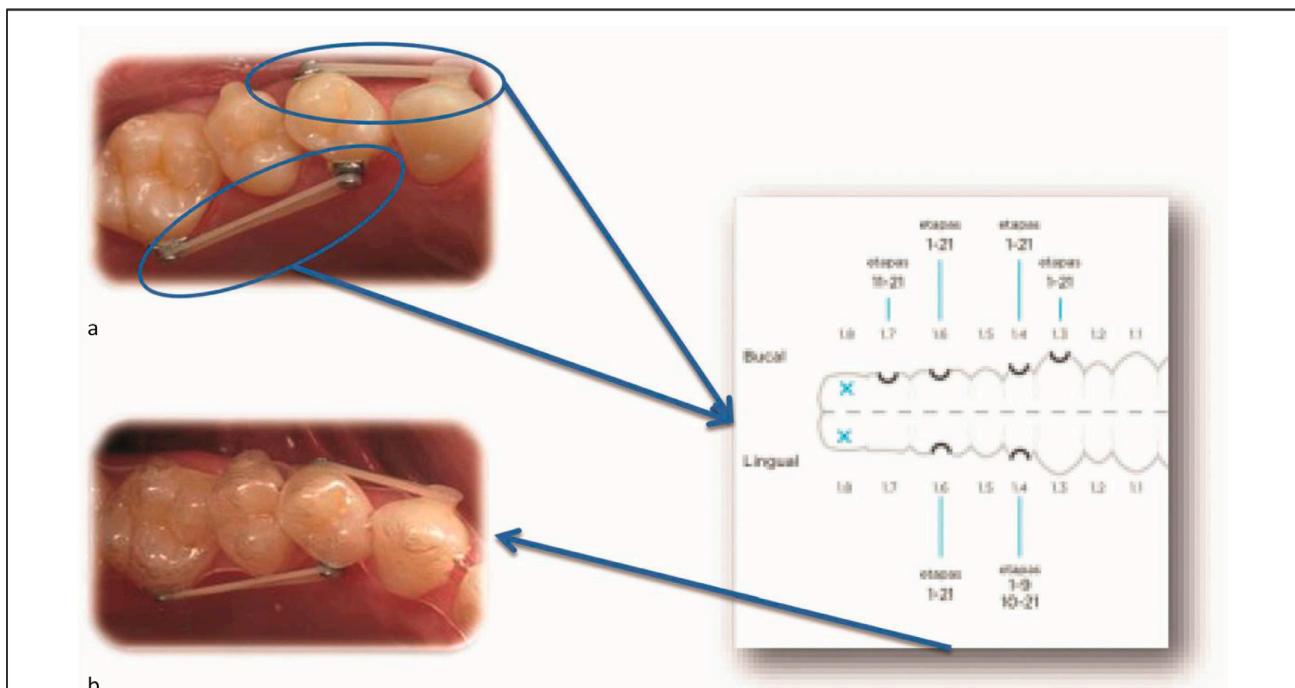
Anticipating “unpredictable” dental displacement

The analysis of the initial situation of the tooth in accordance with the

desired type of tooth displacement is paramount. It must be as comprehensive as possible so as to enable us to achieve our objectives.

Example.

Provided below are images of cases with severe rotations on 16 and 14. The use of accessories, by way of bonded buttons and elastomeric chains, is combined with the use of precision cuts; button



*Figure 48a, b
Notion at the end of treatment.*

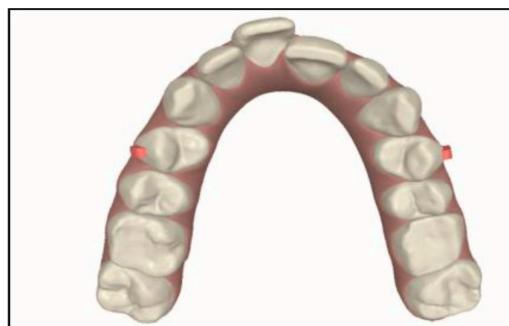
*Figure 49
Previsualization of the cuts.*



*Figure 50
Before treatment.*



*Figure 51
Post treatment.*



*Figure 52
Clincheck.*

cutting is preprogrammed in the ClinCheck treatment plan. (Figs. 48a, b; 49).

The Pretreatment Notion

Once this orthodontic correction has been made, this technique requires the production of a stabilizing splint in prepara-

ration for the aligners. In addition, it usually results in a significant increase in the overall duration of the treatment. Case treated (Figs. 50, 51, 52).

In anticipation of the use of aligners, a pretreatment preparation has been proposed, especially in the cases of severe



*Figure 53
Start of treatment.*



a

b

*Figure 54a, b
Aligner 7 in the mouth adjusted to the auxiliary device.*



a

b

*Figure 55a, b
a. Aligner 14. b. End of treatment.*

rotation and significant dental version with the use of sectional arches.

At present, after a detailed study of ClinCheck, it turns out that I prefer to manage these accessories concomitantly with the aligners and thus avoid lengthening the overall duration of the treatment.

Example: the rotation of 45 is accompanied by an elastomeric chain stretched from the vestibular surface of 45 to 46. Button cutting can either be done manually or programmed into the aligners with ClinCheck (Figs. 53, 54, 55).

Note a slight parasitic rotation movement on 46 and overcorrection on 45, which will be spontaneously corrected

when the auxiliary device is removed and the new aligners are placed.

Making a dental displacement more predictable

Anteroposterior Displacement

Pushing the class-II limits: for Invisalign®, the predictability of class-II treatments is improved in the following cases:

- A class-II malocclusion <2–3 mm
- Mesial rotation of the molars
- Sufficient height of the clinical crown
- A young patient in the growth phase.

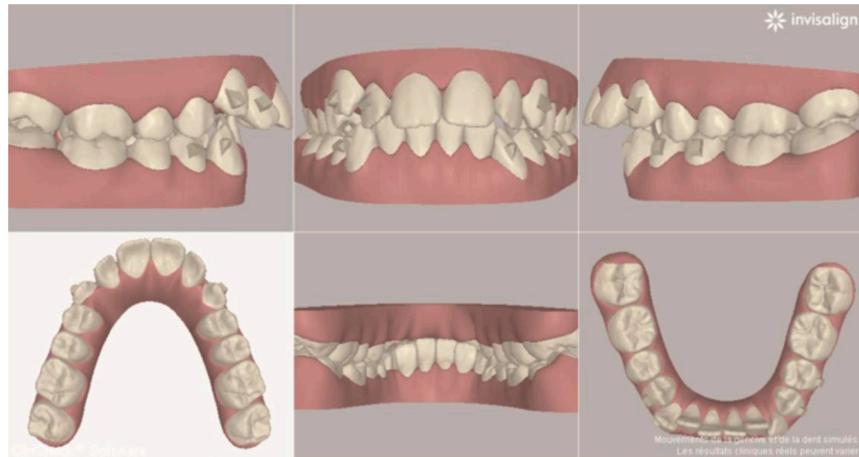


Figure 56
ClinCheck screen shot.

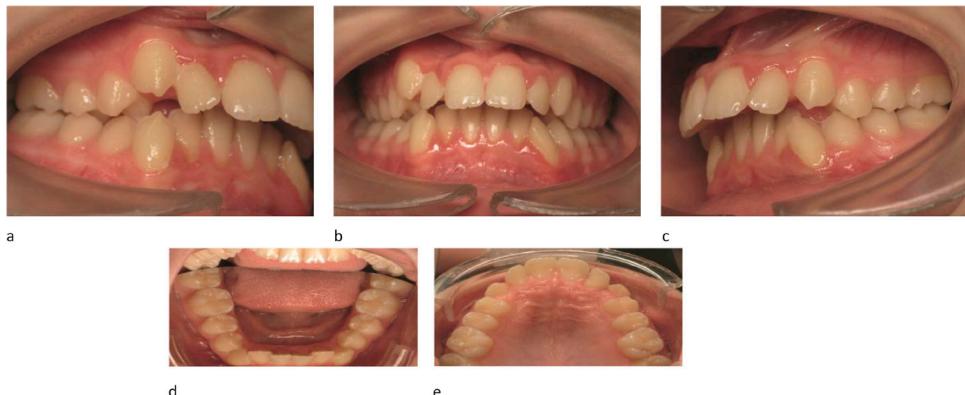


Figure 57a, b, c, d, e
Start of treatment.

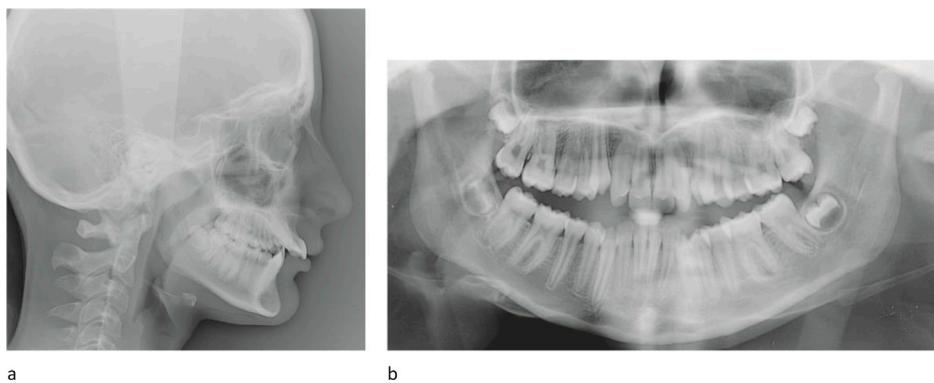
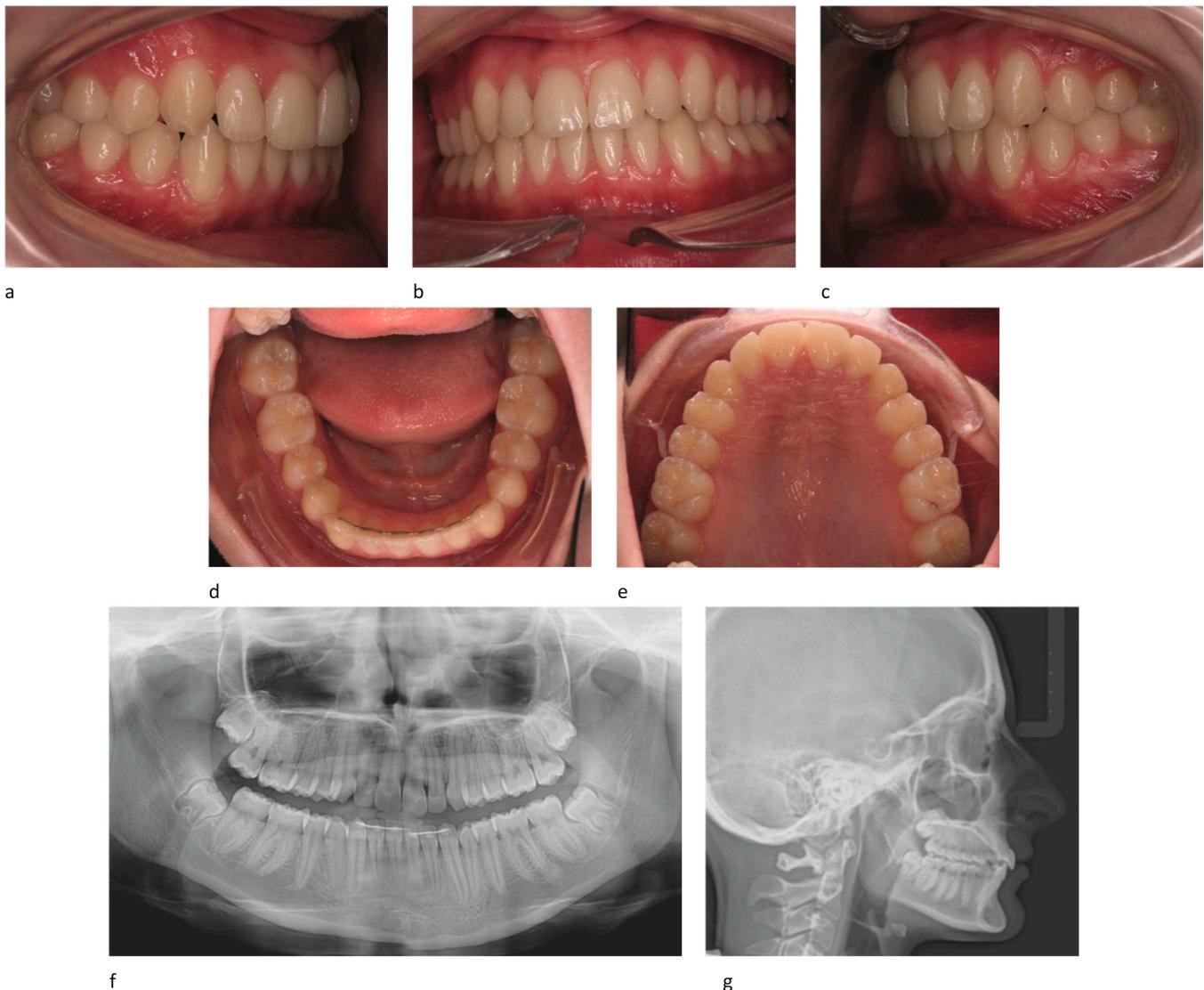


Figure 58
a. Profile X-ray. b. Panoramic X-ray.



*Figure 59a, b, c, d, e, f, g
End of treatment.*

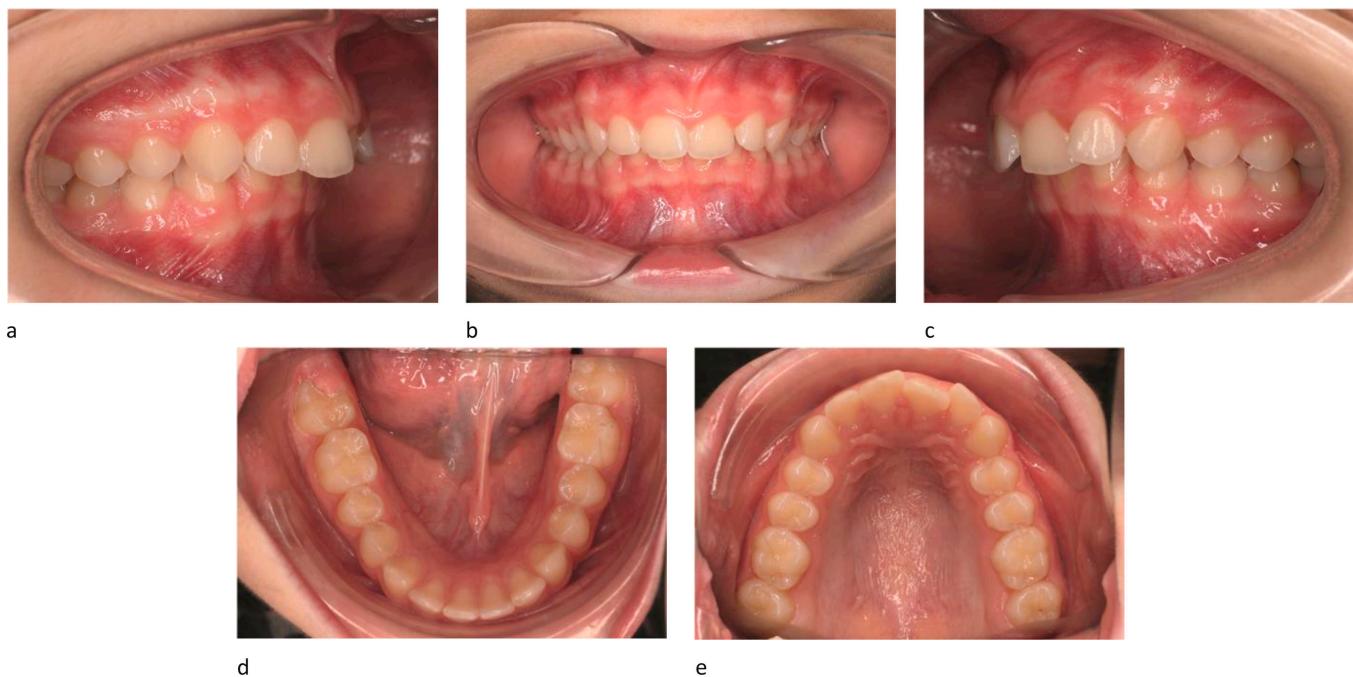
Clinical case 1: class-II DMD (Fig. 56) (Fig. 57a, b, c, d, e; 58a, b; 59a, b, c, d, e, f, g).

In class-II malocclusion >4 mm:

- Either a two-phase treatment can be considered: carrying out the first phase of interception with a class-II propulsion
- or sagittal correctors can be used in conjunction with Invisalign treatments, such as Carriere Distalizer.

Clinical Example 2: complete class II (Figs. 60a, b, c, d, e; 61; 62a, b, c; 63a, b, c; 64; 65a, b, c, d, e).

The occlusal centering of a molar class I is obtained in approximately 6 months, an optical impression is made for the manufacture of additional aligners to finalize the treatment (predicted count during treatment is 32 aligners,



*Figure 60a, b, c, d, e
Start of treatment.*



*Figure 61
Profile X-ray.*



Figure 62a, b, c
Carriere Distalizer.



a

b

c

Figure 63a, b, c
Aligner 12.

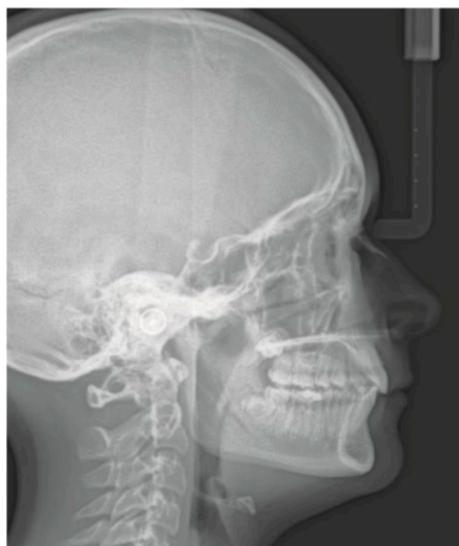
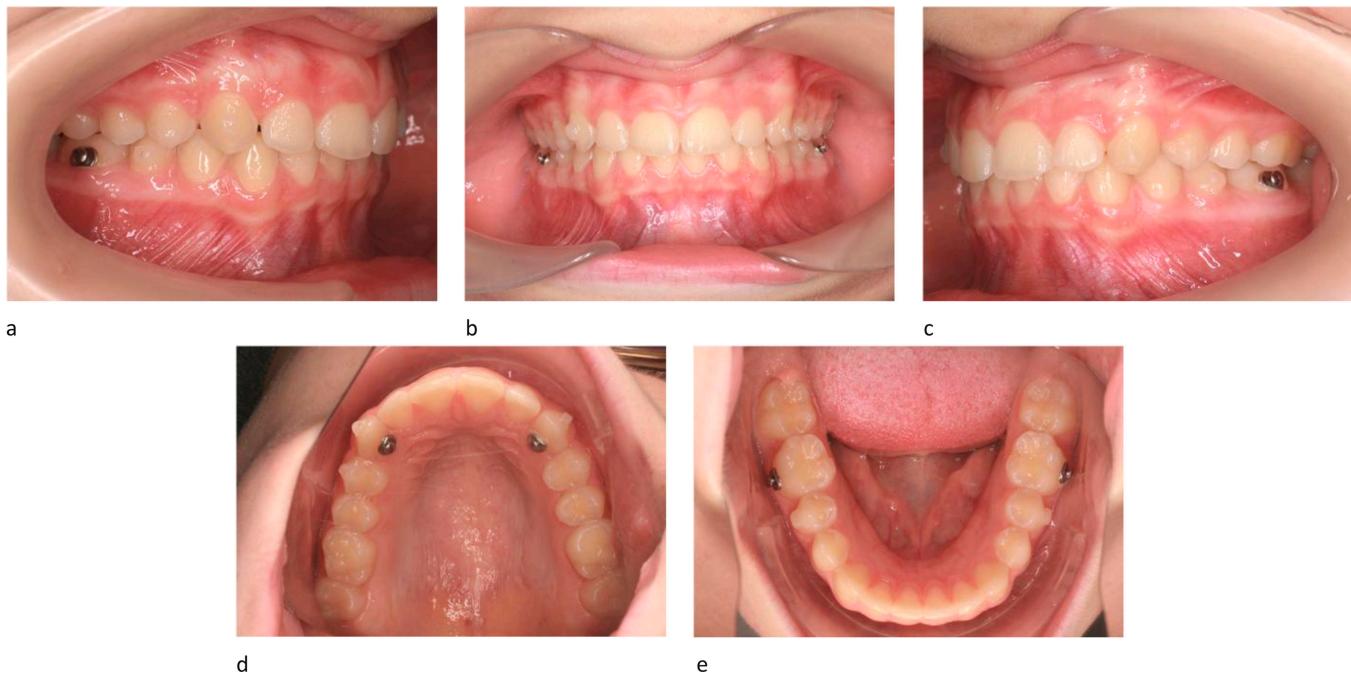


Figure 64
Profile X-ray, aligner 12 upon removal of
the distalizer.



*Figure 65a, b, c, d, e
Intraoperative photo of the end of treatment.*

which means that 43 aligners are predicted to cover the entire process).

Vertical Displacements

Infraocclusions

Effect of aligners on anterior infraocclusions. Major Infraocclusion: aligner

treatments 20 in the 1st phase, and 13 in the finishing phase.

(Fig. 66a, b, c; 67a, b, c; 68a, b, c).

The action of the masticatory forces on the aligners creates a posterior intrusion and therefore favors anterior rotation of the mandible, which results in the closure of the previous infraocclusion. By this induced movement, the



*Figure 66a, b, c
Start of treatment.*



Figure 67a, b, c

Aligner 14. Decreased infraocclusion by the posterior intrusion induced by the aligners.



Figure 68a, b, c

End of treatment a vertical elastic has aided the occlusion of the canines.

treatments by aligners present a credible alternative to the treatment of the infraocclusions^{3,11}.

Supraocclusions

With Invisalign®, the treatments are more predictable:

- If the incisors are retroversed, it will result in a relative intrusion decreasing anterior covering
- If the posterior occlusion is in class I. If we refer to the evaluation sheet for dental movements, the incision movements of 2.5 mm at the incisors and



Figure 69a, b, c

Start of treatment.



Figure 70
Digital impression.



Figure 71
Pure intrusive movement.

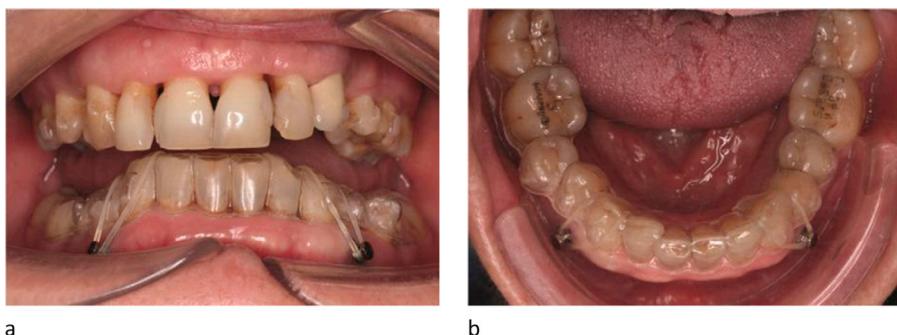


Figure 72a, b
Miniscrews.



Figure 73
End of leveling.

0.5 mm at the premolar level, remain predictable movements.

Beyond this the use of accessories becomes necessary (Fig. 69a, b, c; 70; 71; 72a, b; 73).

Class-II case with complete incisal recovery.

Here the intrusion movement is made possible by the associated and planned use of miniscrews located at the apical level between 33 34 and 43 44. The positioning of the elastics is programmed on aligner 1.

CONCLUSION

For years, there has been a constant technological evolution in the field of orthodontics, and Invisalign has played an integral role in increasing the credibility of aligner treatments as a real alternative to multiattachment treatments.

But apart from these technical and scientific evolutions, there is another paradigm shift, which is equally important to the approach of our cases. This shift relates to the planning of orthodontic treatments. Indeed, ClinCheck will give us a preview of the final result as well as the different steps to achieve it. We then reflect on the treatment, using our clinical experience and orthodontic knowledge, to improve

process predictability and treatment outcomes.

Therefore, although we can only rejoice in the innovation and mastery of the information technology tool provided by Invisalign®, it is important to keep in mind that they are only there to assist us in our treatment and that our clinical intuition remains crucial.

For its mastery in assisting our protocols, this technique, similar to any orthodontic technique, continues to be considered “master on board”.

Thus, we could say, paraphrasing Dr. Steiner on cephalometry, that digitization is a good servant but a bad master.

Conflict of interest: The author states that he is a speaker for Invisalign.

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