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Degree of difficulties and auxiliary techniques in derotation of teeth in orthodontics – A systematic review

Lina Nouri

Dissertação conducente ao Grau de Mestre em Medicina Dentária
(Ciclo integrado)

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Trabalho realizado sob a Orientação da Mestre Selma Pascoal

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Resumo

Introdução: A Ortodontia é uma especialidade da Medicina Dentária que se dedica ao tratamento das maloclusões com o objetivo de otimizar o equilíbrio postural entre as estruturas ósseas, dentárias e musculares para fins funcionais e estéticos. Os alinhadores cada vez mais utilizados em ortodontia apresentam resultados promissores na resolução dos casos clínicos, porém existem movimentos de complexa resolução como as rotações de caninos e pré-molares, de modo que a criação de *attachments* em sistemas de alinhadores poderão ser uma ferramenta terapêutica útil para a resolução dos casos.

Objetivos: Perceber a dificuldade de resolução das desrotações e as técnicas auxiliares que apresentam melhores resultados na resolução deste problema em pacientes com tratamento ortodôntico com alinhadores.

Método: Foi realizada uma busca bibliográfica na base de dados Pubmed em fevereiro de 2022 usando as palavras-chave ((Derotation tooth) OR (tooth rotation) AND (aligners OR Invisalign®))

Resultados: Identificaram-se 406 artigos dos quais 11 foram selecionados considerando os critérios de inclusão e exclusão. Oito estudos estão relacionados com Invisalign®, dois estudos com alinhador PET-G e um estudo com alinhador F22.

Conclusão: As técnicas auxiliares parecem ter um efeito favorável na desrotação dos dentes. Os *attachments* quadrangulares e retangulares verticais parecem ser mais eficientes na desrotação de dentes com alinhadores. A rotação é considerada o movimento menos preciso (46%), sendo mais difícil para caninos, pré-molares e molares.

Palavras-chave: Desrotação dentária, rotação dentária, alinhadores, Invisalign®

Abstract

Introduction: Orthodontics is a specialty of Dentistry dedicated to the treatment of malocclusions with the aim of optimizing the postural balance between bone, dental and muscular structures for functional and aesthetic purposes. We observe in recent years a greater use of aligners, but some orthodontics movements are complicated to achieved with aligners so the creation of attachments in an aligner system can be a useful therapeutic tool to correct a dental malocclusion involving rotations or severe rotations.

Objectives: To find the best auxiliary techniques and difficulties in derotating teeth.

Method: A bibliographic search was carried out in the following Pubmed database in February 2022 using the keywords ((Derotation tooth) OR (tooth rotation) AND (aligners OR Invisalign®))

Results: The search identified 406 articles of which 11 were selected considering the inclusion and exclusion criteria. Eight studies are related with Invisalign®, two studies with PET-G aligner and one study with F22 aligner.

Conclusion: Auxiliary techniques seem to have a favorable effect on derotation of teeth. Quarter-sphere and vertical rectangular attachments seem to have the best efficiency in derotating teeth with aligners. The least accurate tooth movement was rotation (46%) and this mouvement was the most difficult for canines, premolars, and molars. A difficulty related was the vertical force along the axis that cause extrusive forces, another difficulty was the aligner deformation.

Keywords: Derotation tooth, tooth rotation, aligners, Invisalign®

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LIST OF ABREVIATIONS

PET-G: Polyethylene terephthalate glycol

PDL: Periodontal ligament

CAT: Clear Aligner Therapy

CAD: Computer-aided design

1. INTRODUCTION

Orthodontics deals with anomalies in dental positioning. Among the anomalies, we find dental rotations which are defined by a rotation of the tooth around its own axis. One of the causes of rotation is a lack of space, so generally, derotation treatment are combined with other orthodontic treatment. The prevalence of tooth rotation in the general population ranges between 2.2%-5.1%. Rotations are most prevalent in the mandibular premolars and maxillary central incisors. In terms of severity, most rotations are between 45° and 90° from the normal position.(1)

The etiology of tooth rotation is not fully understood. However, multiple genetic and environmental factors may contribute to its development like the presence of supernumerary teeth or severe tooth-size arch length discrepancy.(1)

To solve that, there are different technics for the derotation of the teeth like aligners, the Invisalign® appliance was introduced to public in the late 1990s as a novel method of straightening teeth without braces (2), The creation of attachments increases the geometry of the tooth and enhances the undercuts along the horizontal plane which help in rotational movement.(3) Some authors describe the rotation of conoid teeth like premolars and canines as one of the most difficult to perform with aligners without attachments.(4)

These appliances are based on orthodontic biomechanics which corresponds to the study of the periodontal system in response to the forces applied to it using the principles of physics and mechanics. We can introduce some concepts of it, like the "Force couple", when there are 2 parallel support forces, in opposite directions and with the same intensity. Then the "Centre of resistance", it's the point where, if we exert any force at that point, the solid moves in the direction of the force without rotation. Burstone *et al.* (2015) describe this point at 1/3 of cervical root for single root tooth. And to finish the "Centre of rotation": If the force does not pass through the centre of resistance, it will cause translational and rotational movements. If there is a superposition of the centre of resistance and the centre of rotation, then there is a pure rotational movement.(5)

Rotations are most of the time treated but they are difficult to retain in their new position. This is because they have a very high risk of relapse due to stretching of the supra-alveolar

and transeptal gingival fibres, which readapt very slowly to the old position. Long-term retention is required to achieve the stability of treatment.

A surgical technique can also be used to have a better retention, it called pericision. It's an adjunctive procedure to prevent relapse following orthodontic treatment and in particularly rotational correction. (1)

So, consequently, the aim of this study was to learn about the various auxiliary techniques and the difficulties related to the derotation of the teeth during orthodontic treatment with aligners.

2. MATERIALS AND METHODS

Methodology:

The systematic review followed the PRISMA protocol.

Formulation of the Research Question and selection of Keywords

Definition of the PICO question of the systematic review

Table 1 - PICO considerations

Problem	Tooth derotation
Intervention	Auxiliary techniques in rotated teeth
Comparison	The use or not use of an auxiliary technique with aligners
Outcome	To solve tooth derotation

Eligibility Criteria:

• Inclusion criteria: articles published between 2011 and 2022, randomized controlled clinical trials, *in vivo* and *in vitro* studies; studies with orthodontic treatment with aligners.

• Exclusion criteria: articles not related to the subject of the work, other language than English; clinical case report articles and opinion devoid of critical evaluation.

Key words:

A literature search was performed on PUBMED (via the National Library of Medicine) using the following combination of search terms ((derotation tooth OR tooth rotation) AND (aligners OR invisalign®))

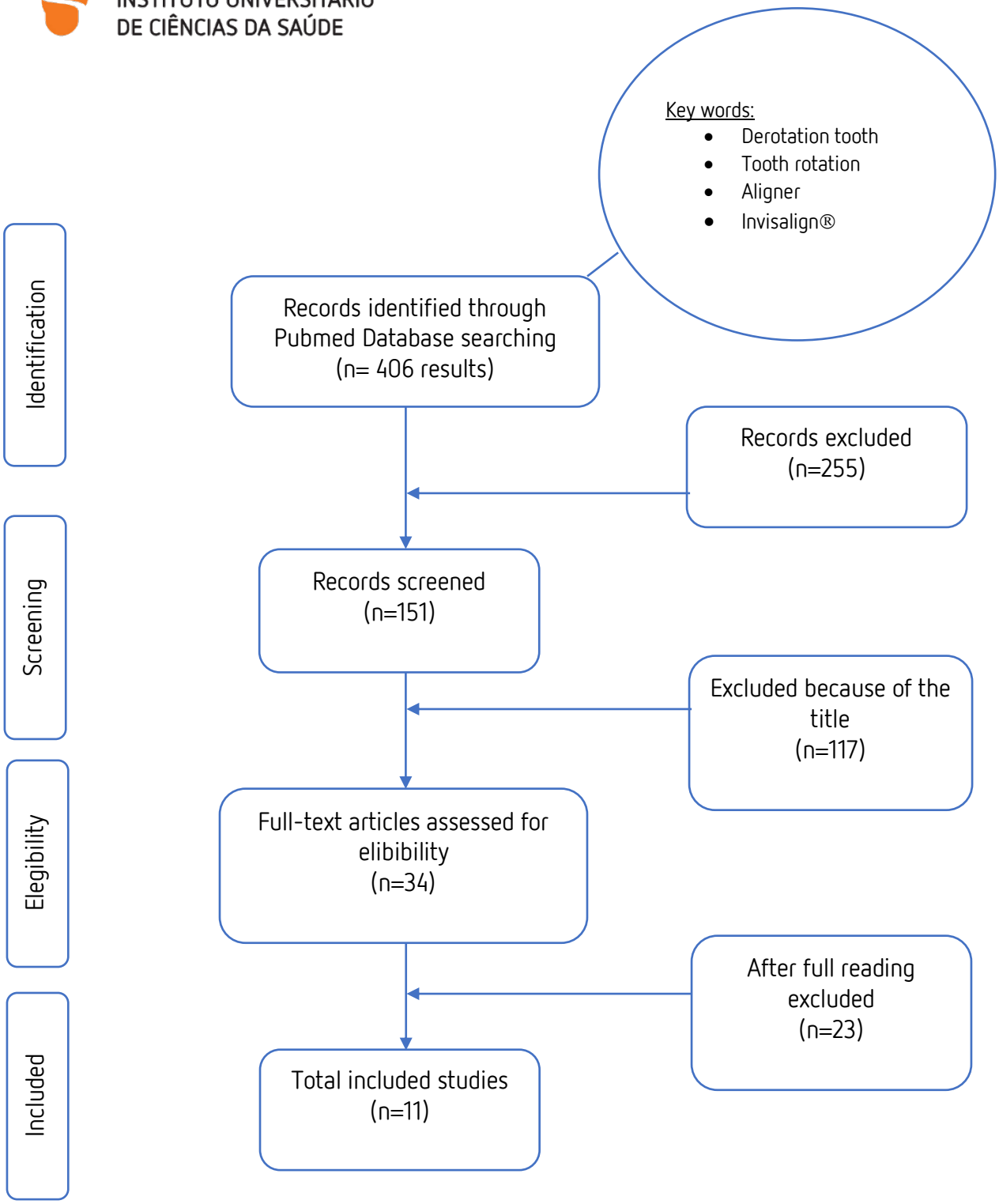

Figure 1 - Flow diagram PRISMA

3. RESULTS

In the total of 34 articles, 11 have been selected considering the inclusion and exclusion criteria.

In these 11 articles, 3 are *in vitro* studies (27,27%) in these studies, 1 is related with invisalign®, 2 with PET-G aligner. 3 are prospective studies (27,27%), all 3 related with Invisalign®. 2 are randomized clinical trial (18,18%) both are also related with invisalign®. 2 are retrospective studies (18,18%) 1 is related with invisalign® and 1 is related with F22 aligner. 1 is a finite element study (9,09%) related with invisalign®.

Table 2 - Details gathered from the selected studies

Title / Author / Date	Types of studies	Purpose	Type of aligner	Study Design	Results
Influence of attachments and interproximal reduction on the accuracy of canine rotation with Invisalign®. A prospective clinical study. Kravitz *et al.* (2008)	-Prospective clinical study	Evaluate the influence of attachments and interproximal reduction on canines un- dergoing rotational movement with Invisalign®.	-Invisalign®	- In this prospective clinical study, 53 canines (33 maxillary and 20 man- dibular) were measured from the virtual TREAT models of 31 participants treated with anterior Invisalign®. A one-way analysis of variance (ANOVA) (*P* .05) compared three treatment modali- ties: attachments only (AO), interproximal reduction only (IO), and neither attachments nor inter- proximal reduction (N). Student's *t*-tests (*P* .05) compared the mean accuracy of canine rotation between arches.	- Vertical-ellipsoid attachments and interproximal reduction do not significantly im- prove the accuracy of canine rotation with the Invisalign® system.
-Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Forces and moments generated by removable thermoplastic aligners: incisor torque, premolar derotation, and molar distalization Simon *et al.* (2014)	-Randomized clinical trial	- Quantify the forces and moments delivered by a single aligner and a series of aligners and the influence of attachments and power ridges on the force transfer.	-Invisalign®	-970 aligners of the Invisalign® system, the aligners came from 30 consecutive patients, of which 3 tooth movements (incisor torque, premolar derotation, molar distalization) with 20 movements each were analyzed.	- Premolar derotation should be supported with an attachment, especially if these teeth have short crowns and few undercuts

Title/Author/Date	Types of studies	Purpose	Type of aligner	Study Design	Results
-Treatment outcome and efficacy of an aligner technique--regarding incisor torque, premolar derotation and molar distalization Simon *et al.* (2014)	-Randomized clinical trial	-Investigate the efficacy of orthodontic treatment using the Invisalign® system and the influence of auxiliaries (Attachment/Power Ridge) as well as the staging (*movement per* aligner).	-Invisalign®	-30 consecutive patients who required orthodontic treatment with Invisalign®. In all patients, one of the following tooth movements was performed: Premolar derotation >10°. All tooth movements were performed in a split-mouth design. The results were compared with the amount of tooth movement predicted by ClinCheck®	-Premolar derotation can be performed using Invisalign® aligners. The staging (movement/aligner) and the total amount of planned movement have a significant impact on the efficacity of the treatment.
-Predictability of orthodontic movement with orthodontic aligners: a retrospective study Lombardo *et al.* (2017)	Retrospective study	- Evaluate the predictability of the effectiveness of F22 aligners	-F22 aligners	-Sixteen adult patients (6 males and 10 females, mean age 28 years 7 months) were selected, and a total of 345 teeth were analysed. Prescribed and real rotation, mesiodistal tip and vestibulolingual tip were calculated for each tooth and, subsequently, analysed by tooth type (right and left upper and lower incisors, canines, premolars and molars) to identify the mean error and accuracy of each type of movement achieved with the aligner with respect to those planned using the setup.	-Without the use of auxiliaries, orthodontic aligners are unable to achieve programmed movement with 100% predictability. Rotation of the lower canines was an extremely unpredictable movement.

Title / Author / Date	Types of studies	Purpose	Type of aligner	Study Design	Results
-Forces and moments applied during derotation of a maxillary central incisor with thinner aligners: An in-vitro study Elkholy. *Et al.* (2017)	-*In vitro* study	-Quantify force and moment components during derotation of a maxillary central incisor when 0.3-mm-thick or 0.4-mm-thick aligners were used instead of conventional	-PET-G aligners	-The test setup consisted of an acrylic model of a maxilla with a separated right central incisor mounted on a 3-dimensional force and moment sensor.	-A significant load reduction can be achieved with the new thinner aligners. Because of the form instability of the 0.3-mm aligner during handling, we suggest the novel sequence 0.4, 0.5, and 0.75 mm for aligner systems based on sequentially increased material thickness.
Accuracy of clear aligners: A retrospective study of patients who needed refinement. Charalampakis *et al.* (2018)	-Prospective study	- Investigate the accuracy of specific tooth movements with Invisalign ®	-Invisalign®	- Three hundred ninety-eight teeth were measured for vertical, horizontal, and rotational movements, and transverse widths were measured. The amount of predicted tooth movement was compared with the achieved amount for each movement.	- All achieved rotations were significantly smaller than those predicted, with the maxillary canines exhibiting the greatest difference of 3.05°

Title / Author / Date	Types of studies	Purpose	Type of aligner	Study Design	Results
-Effect of different attachment geometries on the mechanical load exerted by PET-G aligners during derotation of mandibular canines: An *in vitro* study Elkholy *et al.* (2019)	-*In vitro* study	-Investigate the effect of aligner attachment geometry on the three-dimensional (3D) force and moment (F/M) values exerted during derotation of a mandibular canine.	-PET-G aligners	-The experiment setup comprised an acrylic mandibular arch model with a separated right canine (tooth 43) mounted on a hexapod via a 3D F/M sensor. Aligners with thicknesses of 0.5, 0.625, and 0.75 mm were tested in combination with quarter-sphere, vertical-ellipsoid, and pyramidal attachments bonded to tooth 43.	-The quarter-sphere geometry had the best overall mechanical properties, it induced relatively high rotational moment increases and counteracted unwanted intrusive forces.
Clear aligner orthodontic therapy of rotated mandibular round-shaped teeth: A finite element study. Cortona *et al.* (2020)	-Finite element study	Evaluate the orthodontic rotational movement of a lower second premolar obtained with clear aligners, analyzing different staging and attachment configurations	- Invisalign®	- A CAD model including a complete lower dental arch (with element 4.5 mesially rotated 30°) and the corresponding periodontal ligaments, attachments, and aligner was designed and imported to finite element software.	- Simulations with attachments and 3° of aligner activation exhibited the best performance concerning tooth movement but registered high stresses in the periodontal ligaments, far from the ideal stress levels able to produce tooth rotational movement

Title/Author/Date	Types of studies	Purpose	Type of aligner	Study Design	Results
Has Invisalign® improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign® Haouili *et al.* (2020)	-Prospective follow-up study	- Provide an update on the accuracy of tooth movement with Invisalign®	-Invisalign®	- 38 patients treated with Invisalign® Full or Invisalign® Teen. All teeth, from the central incisor to the second molar, were measured on digital models created from intraoral scans. The types of tooth movements studied were a mesial-distal crown tip, buccal-lingual crown tip, extrusion, intrusion, and mesial-distal rotation.	-The accuracies for mesial rotation of the mandibular first molar was 28% and distal rotation of the maxillary canine was 37%
Efficacy of Invisalign® attachments: A retrospective study. Karras *et al.* (2021)	- Retrospective study	- Compare the efficacy of Invisalign®'s optimized and conventional attachments on rotational and extrusive tooth movements.	- Invisalign®	- Initial, predicted, and achieved digital dental models from 100 orthodontic patients were exported from Invisalign®'s ClinCheck® software as stereolithography files and subsequently imported into the Slicer CMF program. Rotational and extrusive measurements for both optimized and conventional attachments were made on 382 teeth from the superimposition of the initial and predicted models	- The mean accuracy for rotation was 63.2% The most severe planned movements for rotation of 74.0° and extrusion of 4.21 mm had an accuracy of 64%.

Title / Author / Date	Types of studies	Purpose	Type of aligner	Study Design	Results
-*In Vitro* Comparison of Different Invisalign® and 3Shape® Attachment Shapes to Control Premolar Rotation Ferlias.*et al.* (2022)	-*In vitro* study	- Evaluate *in vitro* the differences of various Invisalign® attachments in their effectiveness during derotation of an upper second premolar.	Invisalign®	-A Force System Identification (FSI) machine, comprising two load sensors, was used in this study. Once the corresponding aligner was passively seated on the teeth, 12 different setups (i.e. 11 different attachments and one setup with no attachment at all) were tested by rotating the test tooth 4.5° mesially and 4.5° distally, in increments of 0.45°	-The vertical rectangular attachments were able to generate the highest derotational moment on both mesial and distal rotations but also received the most side effects (intrusive force, torque, and tipping).

4. DISCUSSION

These last years, the popularity of treatment with invisible aligners has led to further research to improve the derotation of teeth, especially during severe rotations.

Simon *et al.* (2014) investigated the treatment efficacy of Invisalign® aligners for the following three predefined tooth movements: incisor torque >10°, premolar derotation <10°, molar distalization >1,5mm. The mean accuracy for premolar derotation was 42.4% without and 37.5% with the support of an attachment. When rotations greater than 15° were attempted, the mean accuracy of premolar derotation decreased by 46%, from 43.3% to 23.6%. In addition to the amount of derotation, the staging (amount of derotation/aligner) also has a considerable impact on the treatment efficacy for premolar derotations with a staging <1.5°/aligner, the total efficacy was 41,8%, whereas with a staging>1,5°/aligner, the accuracy decreased to 23,3%.(6)

They also studied (6) the influence of auxiliaries (attachments, power ridges) to the force transfer, the results show that distalization and derotation supported by an attachment have higher forces or moments corresponding to the direction of movement. With an attachment the initial mean moment for derotation was 8.8 N.mm. Without an attachment, the initial mean moment was only 1.2 N-mm. According to ClinCheck®, the total amount of derotation ranged between 12° and 35°. The staging for the movements with an attachment was between 0.5° and 1.3° per aligner; on average, it was 1.1° per aligner. Without an attachment the amount of derotation per aligner was between 0.4° and 2.1°; on average, it was 1.2° per aligner. Premolar derotation should be supported with an attachment especially if these teeth have short crowns and few undercuts. (7)

Elkholy *et al.* (2019) studied the effect of attachment geometry on the forces and moments delivered by PET-G aligners during derotation of a right mandibular canine.
The results of this study indicate that during distorotation of lower canines, aligners without or with attachment of any type engaged at approximately 2.5°. During mesiorotation, however, aligners without attachment tended to engage at larger rotational degrees of approximately 4,7°, whereas engagement angles for aligners with attachment were smaller, ranging between 1,4° and 2,7° of mesiorotation. Hence, in addition to a general increase in rotational stiffness, attachment also enable the aligner to exert rotational moments on

canines during quite small rotations. Of the three attachment geometries investigated, the vertical-ellipsoid and quarter-sphere types induced clearly higher rotational moments during mandibular canine derotation.(8)

For the correction of mesially rotated lower canines, they recommend the use of attachment even for small derotation ranges, to compensate for the relatively late aligner engagement without attachment. The quarter-sphere attachment had the best capability to prevent intrusive forces during derotation of distorotated mandibular canines. (8)

Elkholy et al. (2017) also studied the biomechanical behavior of aligners with reduced thicknesses, 0.3 mm, and 0.4 mm, compared with 0.5-mm aligners, the thinnest currently available. The 0.3 mm and 0.4 mm aligners resulted in substantial average reductions of rotational stiffness for mesiodistal derotation of a maxillary central incisor by 76% (0.3 mm aligner) and 45% (0.4 mm aligner). Similar results were obtained in another study examining bodily movements in the labiopalatal direction. From these findings, they concluded that thinner aligners may have the potential to reduce or even prevent the overloading of the teeth during aligner treatment observed in previous experimental and clinical studies. An additional finding of this study was that the regularity of the stiffness increases in 1 aligner sequence could be increased by including either the 0.3 mm or 0.4 mm aligner instead of the 0.625-mm aligner. Hence, thinner aligners might reduce the risks of tooth overloading and root resorption. (9)

Ferlias *et al.* (2022) demonstrate the variability between the different shapes and types of attachment used in aligner treatment. Most importantly, this shows that a rotation of 4.5° in the aligner creates high moments at a level that most likely exceeds the moments needed for effective derotation. Therefore, it would make sense to not exceed 1.5° of derotation *per* step in aligner staging. Besides, Simon *et al.* (2014) has shown that the efficacy of tooth movement decreases significantly with a staging larger than 1.5°/aligner (6). This is probably the reason why Invisalign® decided that the derotation provided by one stage never exceeds 2°(4). The study of Cortona *et al.* (2019) also demonstrate that it seems reasonable to not exceed 1,2° of rotation per aligner(10)

If they focus purely on the amount of moment created to derotate the tooth the results show that the vertical rectangular attachment outperformed the others by creating the

largest moments when the tooth was rotated either mesial or distal (4), while in the study of Elkholy *et al.* (2019) (8) it was the vertical ellipsoid the most effective.

Ferlias *et al.* (2022) studied 12 setup, 11 different geometry of attachment and one setup without Att. They observed that the attachment with a geometry of the HemiEllip created the highest moment but only when the tooth was rotated mesial (disto-rotation). Furthermore, the no attachment setup exhibited the least amount of derotational moment for both mesial and distal rotations. (4)

In the same study of Ferlias *et al.* (2022), it was also interesting to observe that the attachment with a geometry of ElliPair generated almost twice as much derotational moment, when the tooth was rotated distal compared to the opposite direction. It seems that during mesio-rotation, the attachment positioned more occlusal can generate almost twice the amount of moment compared to the other. (4)

Lombardo *et al.* (2017) demonstrate that the mean accuracy of orthodontic movement provided by the F22 aligner is 73.6%, considering all movements in both anterior and posterior teeth, while it falls to 70.6% if only the anterior teeth are considered. The mean rotation error was significantly greater at the lower canines than at the lower incisors and molars.(11) There were no significant differences in the accuracy index between tooth movements, except for upper incisor rotation, which was significantly lower to that achieved at the lower premolars. (11)

In a finite element study, Cortona *et al.* (2020) show that the rotation of round-shaped teeth remains one of the less predictable movements in Clear Aligner Therapy (CAT), with a CAD model of mandibular arch, they evaluated the rotation (30°) of the right second premolar (tooth 45). The teeth from 37 to 47 were involved in the aligner. (10)

They studied 6 different setups, each one was with two different degrees of activation (1,2° and 3°), this mean that for each aligner applied, they exerted an activation of 1,2° or 3°. So the different setup was without attachment: No attachment (1,2°) and No attachment (3°), attachment on tooth 45: attachment 45 (1,2°) and attachment 45 (3°) and to finish attachment on tooth 44 and 46 : attachment 44-46 (1,2°) and attachment 44-46 (3°). (10) They concluded that the most efficient combination regarding to displacement/anchorage and loss/PDL stress ratio was the attachment 45 (1,2°) because it provides a clockwise

rotation of 0,26°. They also concluded that the initial lower premolar rotations of 0,2° *per* aligner is obtainable with vertical rectangular attachment (10).

Charalampakis *et al.* (2017) demonstrated that the rotations predicted was higher than the achieved ones. The median differences ranged from 0,9° to 3,05°. Rotation of maxillary and mandibular canines were the most unpredictable. They also suggested overcorrecting the tooth can be the solution of the problem(2).

Haouili *et al. (2020)* (12) studied the accuracy of Invisalign®, they found that the least accurate tooth movement was rotation (46%), and this movement was the most difficult for canines, premolars, and molars. Simon *et al.* (2014*)* (6) and Charalampakis *et al.* (2017*)* (2) had similar findings. Also, the SmartTrack features automatically placed optimized attachment for rotational movements greater than 5°, rounded teeth are still difficult to be retained by aligners (12).

Karras *et al.* (2021) compared the efficacy of optimized and conventional attachment, they also compared which was predicted and what was achieved for both attachments. The results showed that for optimized attachment the maxillary premolar has the most predicted/ achieved ratio (3,54°), they predicted 12,65° and they achieved 9,68° and the least predicted/achieved ratio (5,74°) was the mandibular premolar, they predicted 14,42° and they achieved 9,62°. For the conventional attachments, the most predicted/achieved ratio (4,45°) was for the maxillary canine, they predicted 11,18° and achieved 7,11°. And the least predicted/achieved ratio (6,86°) was the maxillary premolar, with a prediction of 11,94° and 5,08° of achievement. They concluded that the attachment could do a huge difference on the efficacy of the aligner (13). As Charalampakis *et al.* (2017) (2), Karras *et al.* (2021) (13) also suggested to overcorrecting rotations by 5 ± 1° to improve accuracy with the Invisalign® system.

For Kravitz *et al.* (2008) (3), there was no significant difference in accuracy of rotation between canines with attachment only, interproximal reduction only, or neither attachment nor interproximal reduction. Labially placed, centrally located, vertical-ellipsoid attachments were the most prescribed attachment shapes for correcting malrotations, like in the study of Elkholy *et al.* (2019) (8) it was the vertical ellipsoid the most effective.

Kravitz *et al.* (2009) shows that for rotations greater than 15° were attempted, the efficacy of the movement decreases from 35,8% to 14,1% for maxillary canines and from 27,9% to 15,9% for mandibular canines. The same study also reported that for rotations greater than 15°, accuracy significantly fell by up to 52,5% (14).

Even though Kravitz *et al.* (2008) found that the presence of attachments did not significantly improve the accuracy of canine rotation (3).

Simon *et al.* (2014) found in their study a mean accuracy of 37,5° and 42,4° for premolar derotation >10° with and without attachment, respectively, but no with statistical difference. They also found a decrease in accuracy for movements higher than 15°, from 43,3% to 23,6% (6).

Lombardo *et al.* (2017), showed that there is an even further significant reduction, the accuracy of upper canine rotations greater than 15° was 19% with F22 aligners (11).

Invisalign® suggests that rotation of canines and premolars until 45° can be considered predictable, from 45 to 55° moderate and up to 55° difficult to accomplish. Invisalign® also asserts that it can resolve, without the use of additional techniques, rotations of 40° in upper and lower central incisors, 45° in canines and premolars, 30° in lateral incisors, and 20° in molars (15).

Tooth derotation present some difficulties, a common side effect Ferlias *et al.* (2022) (4) encountered in all the attachment setups were the vertical forces created along the long axis of the tooth, which in almost all occasions were intrusive. When the tooth was rotated mesially, all setups showed an intrusive force in a quite substantial amount which in most surpassed 100cN, the geometry of 3Shape attachment has the highest intrusive force in comparison with others geometry of attachment. This far exceeds the recommended level of force needed for intrusion of 10-20 cN, which of course raises questions of higher risk of root resorption. Due to the convexity of the crown, the force delivered to the tooth by the aligner when analyzed into the three-axial coordinate system almost always comes with an intrusive component which seems to be independent of any attachment used (4). Elkholy

et al. (2017) also related high collateral intrusive forces were observed for both mesiorotation and distorotation reaching maximum force of 16,96 N and 19,70 N respectively. (9)

Cortona *et al.* (2020) compared the efficacity of different techniques on derotation. For each technique there were different amounts of clockwise rotation in the horizontal plane. Aligner activations of 1,2° and 3° were analyzed. The 3° value was selected following the recommendations of some clear aligner manufactures, while 1,2° was the mean aligner activation for tooth rotation. The degrees of activation are the degree of rotation exerted *per* aligner on the tooth. Hence, the authors revealed some difficulties in these techniques, like the aligner deformation, with attachment on tooth 45 and 3° of activation of the aligner where they were detected highest deformation on the aligner distal surfaces of tooth 37 and 47. Also, all the aligner with 3° activation of aligner models detected anchorage loss on element 44. But also, unpredicted vertical movements were detected on both the attachment of the tooth 45 and 3° of activation of aligner and attachment of the tooth 44 and 46 and 3° of activation of aligner, they also showed intrusive forces focused on tooth 47 which moved 0,025mm and 0,032mm, respectively. (10)

5. CONCLUSION

- The Derotation of canine or premolar are difficult to exert with aligners without the aid of an attachments. For canine the quarter-sphere geometry was the best and for premolar the vertical rectangular one. For mandibular premolar the vertical rectangular attachment labially placed is efficient.
- The premolar derotation depend on the staging (movement/aligner) and the velocity.
- Invisalign® recommended to not exceed an activation of 2° *per* aligner.
- The predictability of orthodontic movement shows that without the use of auxiliaries like attachments, the programmed movement was not achieved at 100%.
- Some authors suggest overcorrection to help in tooth derotation.
- Some side effects were registered like vertical forces along the axis like intrusive forces.
- This technique presents difficulties during its realization but also after, therefore the rest of the treatment must be well taken care of to avoid the failure of the treatment.

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