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Effectiveness and Predictability of Clear Aligners Regarding Premolar and Canine Derotation

Luca Mangiaracina

Dissertação conducente ao Grau de Mestre em

Medicina Dentária (Ciclo Integrado)

Gandra, 5 de junho de 2020

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Trabalho realizado sob a Orientação de Prof. Doutora Teresa Pinho e Mestre Selma Pascoal

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Declaração de Integridade

Eu, acima identificado, declaro ter atuado com absoluta integridade na elaboração deste trabalho, confirmo que em todo o trabalho conducente à sua elaboração não recorri a qualquer forma de falsificação de resultados ou à prática de plágio (ato pelo qual um indivíduo, mesmo por omissão, assume a autoria do trabalho intelectual pertencente a outrem, na sua totalidade ou em partes dele). Mais declaro que todas as frases que retirei de trabalhos anteriores pertencentes a outros autores foram referenciadas ou redigidas com novas palavras, tendo neste caso colocado a citação da fonte bibliográfica.

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Eu, **Teresa Pinho,** com a categoria profissional de "**Professor Auxiliar com Agregação"** do Instituto Universitário de Ciências da Saúde, tendo assumido o papel de Orientador da Dissertação intitulada ***"Effectiveness and Predictability of Clear Aligners Regarding Premolar and Canine Derotation"***, do Aluno do Mestrado Integrado em Medicina Dentária, **Luca Mangiaracina**, declaro que sou de parecer favorável para que a Dissertação possa ser depositada para análise do Arguente do Júri nomeado para o efeito para Admissão a provas públicas conducentes à obtenção do Grau de Mestre.

Gandra, 5 de Junho de 2020

O Orientador

_____

Agradecimentos

Quero agradecer á minha orientadora Prof. Doutora Teresa Pinho, por me ter possibilitado descobrir realmente o mundo da ortodontia para além dos livros, foi uma honra e um privilégio poder ficar ao seu lado durante este ano. Esta experiência foi fundamental para perceber como é imprescindível entusiasmo para aprender, precisão e perseverança todos os dias.

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A mio fratello Marco. Grazie per avermi fatto prendere sempre la strada giusta nella vita.

Resumo

O objetivo deste estudo foi avaliar a previsibilidade e a efetividade da rotação dos caninos e pré-molares com o sistema Invisalign®. Foi realizada uma pesquisa na base de dados PUBMED com as seguintes palavras chaves: "Orthodontic" AND "Clear aligner therapy" OR "Invisalign" AND "Rotation". Selecionaram-se 3 artigos com interesse para este estudo. A amostra foi constituída por 101 pacientes tratados com o Sistema Invisalign® pela Prof. Doutora Teresa Pinho, divididos em grupos dependendo da quantidade de rotação a efetuar: (A) 5° a14,9°, (B) 15° a 24,9°, (C) 25° a 34,9°, (D) 35° a 44,9° e (E) >45°. Os dados dos movimentos prescritos nos Clincheck® foram analisados com recurso ao SPSS®. Foi estudada a influência dos attachments na eficácia do tratamento, bem como a presença de auxiliares, entre os quais botões associados a elásticos e aparelhos fixos seccionais. O movimento de rotação em dentes redondos, tais como premolares e caninos é considerado um dos mais difíceis devido á anatomia dos dentes, no presente estudo mostraram um aumento da eficácia e previsibilidade do movimento, provavelmente devido á introdução de novos materiais (SmartTrack®) e novas tecnologias associadas ao Sistema Invisalign®. Para graus maiores de rotação, é aconselhado utilizar auxiliares para evitar a perda de ancoragem e acelerar o movimento. Sequenciar o movimento e criar espaço antes da rotação é fundamental para diminuir o grau de complexidade do movimento. Para rotações menores de 35° o tipo de attachment, otimizado ou convencional, não parece ter nenhuma influência na concretização do movimento.

Palavras-Chave

Tratamento ortodôntico; Alinhadores; Invisalign; Desrotação de pré-molar; Desrotação canina

Abstract

The aim of this study was to evaluate the predictability and effectiveness of canine and premolar rotation with the Invisalign® system. A search was conducted in the PUBMED database with the following keywords: “Orthodontic” AND “Clear aligner therapy” OR “Invisalign” AND “Rotation”. 3 articles of interest for the study were selected. The sample consisted of 101 patients treated with Invisalign® by Prof. Doutora Teresa Pinho, divided into groups depending on the amount of rotation to be performed: (A) 5°-14.9°, (B) 15°-24.9°, (C) 25°-34.9°, (D) 35°-44.9° and (E) >45°. The movement data prescribed in the Clincheck® were analyzed with SPSS®. The influence of attachments on treatment effectiveness was also studied, as well as the presence of button-type aids associated with elastics and sectional fixed appliances. The rotation movement of round teeth, such as premolars and canines is considered one of the most difficult due to its anatomical shape, this study showed an increase in the effectiveness and predictability of the movement, probably thank to the introduction of new materials (SmartTrack®) and new technologies associated to the Invisalign® system. For higher degrees of rotation, it’s advisable to use auxiliaries to prevent loss of anchorage and accelerate the movement. Sequencing the movement and creating space before rotation is essential to decrease the degree of complexity of the movement. For rotations <35 ° the type of attachment, optimized or conventional, does not seem to have any influence on the realization of the movement.

Keywords

Orthodontic treatment; Clear aligners; Invisalign; Premolar derotation; Canine derotation

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LIST OF ABBREVIATIONS

M0 – analysis of the case at the end of the initial phase

M1 – analysis of the case at the end of the 1st refinement

M2 – analysis of the case at the end of the 2nd refinement

M3 – analysis of the case at the end of the 3rd refinement

M4 – analysis of the case at the end of the 4th refinement

M5 – analysis of the case at the end of the 5th refinement

M6 – analysis of the case at the end of the 6th refinement

M7 – analysis of the case at the end of the 7th refinement

1.INTRODUCTION

The seeking of more aesthetic and comfortable ways for treating patients orthodontically than with conventional fixed appliances culminated with the introduction of the Invisalign® system in 1999 (1)(2)(3). It consists of a series of plastic aligners interchanged every 7 to 14 days, with the purpose of delivering forces to the tooth surface, developing a force system able to perform orthodontic tooth movements (4). While in the beginning it was only possible to treat mild malocclusion, like minor crowding and space closure, with the introduction of innovations such as optimized attachments and aligners activations like power ridges or pressure areas, it is now possible to perform controlled tooth movements (5)(6)(7)(4) . Among the tooth movements, different studies considered that rotations are one of the most difficult movements to accomplish with clear aligners, secondarily to extrusion, particularly the derotation of round teeth such as premolars and canines (1)(4)(8)(9). Invisalign® clear 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. A review of the scientific literature was performed related to the topic, before proceeding with the clinical study. The aim of this clinical and experimental study was to investigate the movements accuracy and predictability of the Invisalign® aligners regarding to canine and premolar derotation. For this purpose, it was compared the difference between the amount of tooth movement predicted by the ClinCheck® software with the amount achieved in the first additional aligners, to test the effectiveness of the movement depending on variables such as amount or rotation needed, type of attachment used and the use of auxiliaries. The use of any auxiliaries such as buttons and/or sectional fixed appliances to aid the movement were taken into account.

2.MATERIALS AND METHODS

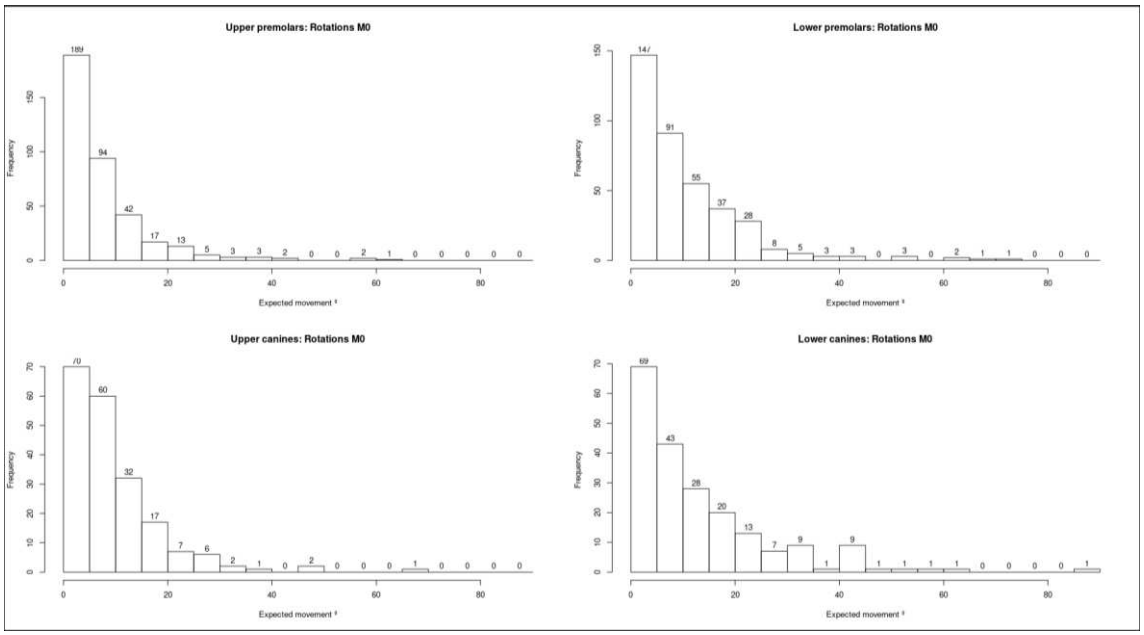
A literature search was performed on PUBMED (via National Library of Medicine) using the following combination of search terms: “Orthodontic” AND “Clear aligner therapy” OR “Invisalign” AND “Rotation”. The inclusion criteria involved articles published in the English language, up to December 2019, reporting the accuracy and effectiveness of premolar and canine derotation. An analysis of the titles and abstracts of potentially relevant articles was performed. The eligibility exclusion criteria used for article searches also involved: case reports; date of publication before 2008; articles not related to the topic. The total of articles was compiled for each combination of key terms and therefore the duplicates were removed using Mendeley citation manager. A preliminary evaluation of the abstracts was carried out to establish whether the articles met the purpose of the study. Selected articles were individually read and evaluated concerning the purpose of this study. To carry out this investigation, digital models and intraoral photographs of 101 patients treated between 2016 and 2020 were sequentially selected to this study. All patients undergoing orthodontic treatment, started from 2016 to 2018 and had to have at last 2 years, treated exclusively with Invisalign® aligners by Prof. Doutora Teresa Pinho in her private orthodontic practice in Porto, Portugal. Patient consent in writing was requested to the research procedures. The study was approved by the Ethics Committee of the Instituto Universitário de Ciências da Saúde. The inclusion criteria were healthy patients, treated with Invisalign®, with the necessity to perform a premolar derotation or/and permanent canine derotation ≥5°. The exclusion criteria were patients with dentofacial syndromes or deformities, periodontal and dental disease, current use of any non-steroidal anti-inflammatory medication, estrogen, calcitonin or corticosteroids. They were also excluded patients that needed mini-screws to aid the orthodontic movement. With these criteria set, all patients were selected for the study. The digital models of the initial situation and at each refinement were done by one orthodontist with an intraoral scanner (iTero Element®, 3Shape Dental Systems, Copenhagen, Denmark), as well as the intraoral photographs to compare expected results with clinical results. Subsequently, the patients were divided in 5 groups depending on the degree of rotation to be accomplished on a specific tooth: (a) rotations comprised between 5° and 14.9°, (b) rotations comprised between 15° and

24.9°, (c) rotations comprised between 25° and 34.9°, (d) rotations comprised between 35° and 44.9° and (e) >45°. It was also noted if attachments (optimized or conventional) or auxiliary techniques were used to help the correction of the tooth malposition and the time when it was placed. Clinical experience suggests that when more than one difficult movement must be performed on the same tooth, like rotation and extrusion/intrusion, it is better to sequence it in order to accomplish the desired position. When the derotation was associated to a vertical movement, intrusion ≥0.5mm or extrusion ≥2.5mm on canines and intrusion or extrusion on premolars, the movement would be considered less predictable, being considered separately. To study the accuracy of the Invisalign® system, the tooth movement planned for each patient was regrouped in a dataset and analyzed with SPSS® in order to create graphics showing (if was used any attachment to realize the movement, how much of that movement occurred from the initial phase to the next refinement and if any auxiliaries were used to aid the tooth movement) the required tooth movement through the treatment. The different moments of the treatment are shown in the graphs In the horizontal axis and referred as "M" (M1, M2, M3, M4, M5, M6, M7), and correspond to the patient's refinement.

3.RESULTS

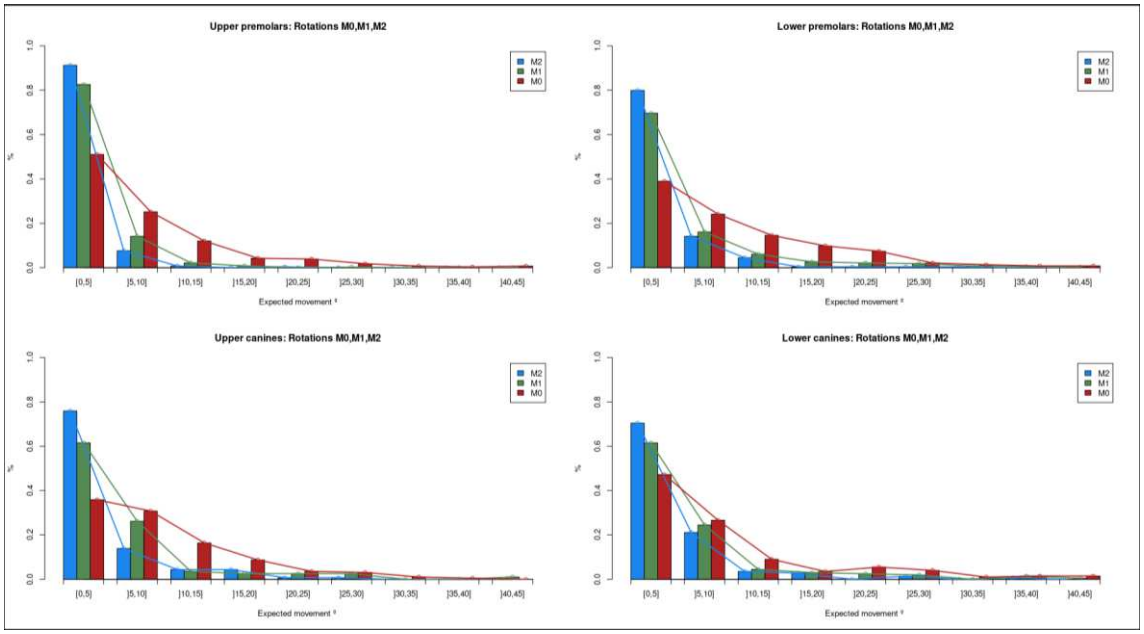
A total of 101 patients were selected based on the inclusion criteria and a total of 1157 tooth movements were investigated. From the total sample, 371 were upper premolars (UPM), 284 lower premolars (LPM), 204 lower canines (LC) and 198 upper canines (UC). Twenty-one teeth of 9 patients were excluded because mini-screws were used to aid the movement. The distribution of the sample is shown in Table 1. Most of the teeth have an amount of rotation up to 5°, and so they were not considered once they are not relevant for the purpose of the study. The sample was divided into the respecting groups according to the amount of movement needed, 445 teeth were included in group A with rotations between 5° and 14,9° (136 UPM, 146 LPM , 92 UC, 71 LC), 152 in group B between 15° and 24,9° (30 UPM, 65 LPM, 24 UC, 33 LC) , 45 in group C between 25° and 34,9° (8 UPM, 13 LPM, 8 UC, 16 LC), 22 in group D between 35° and 44,9° (5 UPM, 6 LPM, 1 UC, 10 LC) and 18 in group E >45° (3 UPM, 7 LPM, 3 UC, 5 LC). Group A accounted for 65,2% of the sample, Group B 22,9%, group C 6,6%, group D 3,2% and E (>45°) 2,6%.

Table 1. The frequency of the rotations to be accomplished at the initial moment (M0) are regrouped by the amount prescribed by the clinician in the Clincheck® and the group of teeth (superior premolars, inferior, premolars, superior canines, inferior canines). The majority of rotations are comprised in the first column (between 0° and 5°) but were not taken into account according the absence of value for the purpose of the study.



The variations between M0, M1 and M2 are shown in Table 2. We can see how at the initial moment (M0, red) 35% to 50% of the teeth have an amount of rotation prescribed between 0° and 5°, and this percentage gradually decrease as the amount of rotation rises (apart from UC from [15°,20°] to [20°,25°]). At the first refinement (M1, green) the [0°,5°] column increases to reach a percentage comprised between 60% to 80%, and the other columns decrease gradually (apart from [25°,30°] LPM). At the second refinement (M2, blue) we can see an ulterior improvement of column [0,°5°] that reaches a percentage from 70% to 90%, with a decrease or disappearing of the other columns (apart from [10°,15°] and [15°,20°] UC).

Table 2. Total amount of movements to resolve in percentage (%) and divided by groups of 5° each. Different moments of the treatment were divided by color: initial moment in red (M0), first refinement in green (M1) and second refinement in blue (M2).



The distribution of the rotations divided for each moment of the treatment are shown in Table 3. It was placed an inferior limit of 5° in order to make the graph more readable. We can see from the graph at the initial moment (M0, red) a wide range of prescribed rotation with an average ranging from 10° to 15° depending on the teeth (10° UPM, 10° LPM, 15°UC, 12,5° LC). Across the treatment we can notice a substantial decrease in the number of teeth from M0 to M1 and from M1 to M2, leaving a few corrections mostly under 20° to correct in the rest of the refinements. Some minor rotations are still present in M3 and M4, although the amount of rotation to be performed has decreased on average, and most of them are corrected through M5 and M6 with just some teeth

left with some minor rotations (less than 10°) to be accomplished. The graph shows how higher rotation seems to be more complicated to correct from initial moment to first and second refinement and were fixed with the aid of auxiliaries like buttons and Cutouts® supported by a powerchain, overcoming the aligner's limitations.

Table 3. Distribution of rotations depending on the moment of the treatment. Each dot corresponds to a tooth and is placed in the vertical axis depending on the degree of rotation prescribed. On the horizontal axis are displayed different moments of the treatment (M0, M1, M2, M3, M4, M5, M6).

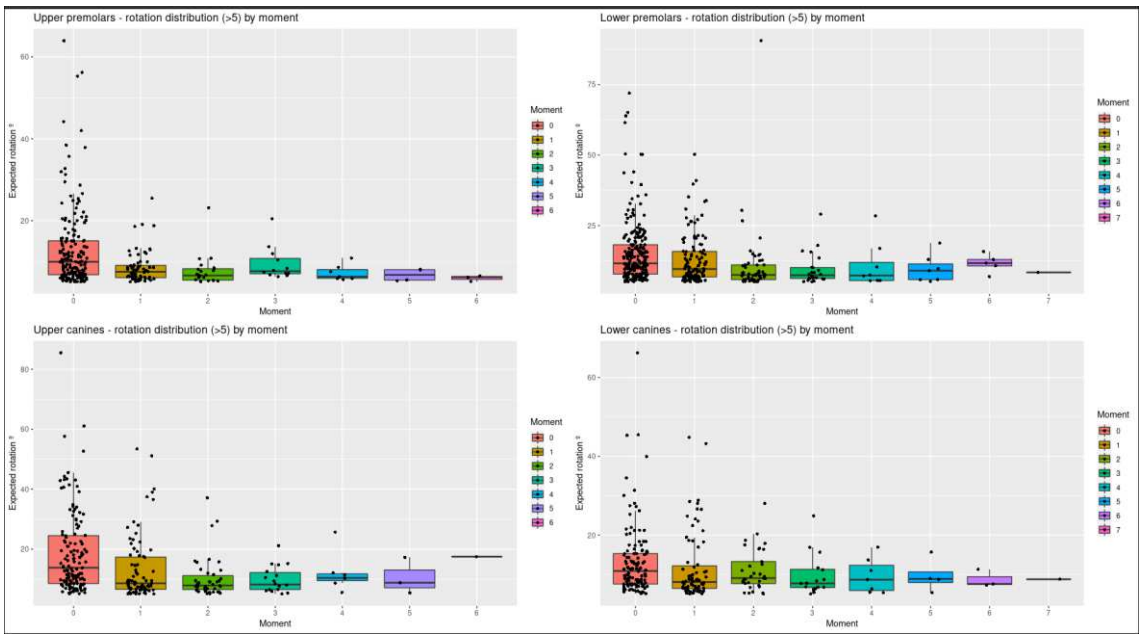


Table 4 shows the amount in percentage of solved rotations depending of the prescribed angle in M0. The vertical axis indicates the amount of accomplished rotation and the horizontal axis the moment of the treatment. We can see how from M0 and M1 most of the smaller rotations have already been corrected (blue line, from 5° to 15°, with 72% of the rotations corrected), and as the amount of rotation increases, the effectiveness decreases. Between M1 and M2 the curve of the 35°-45° increases its inclination, showing an increased rate of correction of the rotation. At M4, M5, M6 and M7 already more than 90% of the rotations have been solved. Also, in Table 5 we can observe that there is no significant statistical difference whether an optimized or a conventional attachment was used in the correction of the tooth's position. Group D, E and F were excluded for this graph because of the small sample size and variables such as the use of an auxiliary among the treatment. In Table 6 we can see how in the first 3 groups no statistically relevant difference was found between superior and inferior teeth, and in

the last two group the small sample size keeps us from being able to observe any relevant result.

Table 4. The graph shows the percentage of solved rotations in function of the predicted angle in M0. The different groups are divided by color. The vertical axis shows the amount of solved movements and the horizontal one the different treatment's times.

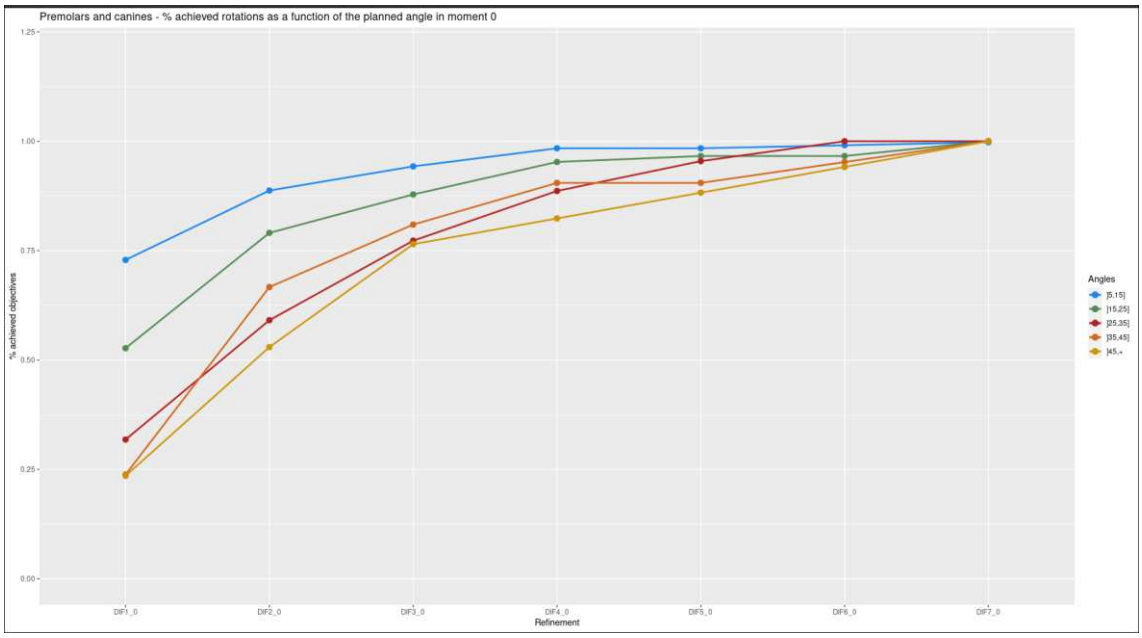


Table 5. Amount of solved rotation compared to the type of attachment utilized to correct it. No statistical differences can be observed between Optimized (blue) and Conventional (green) curves.

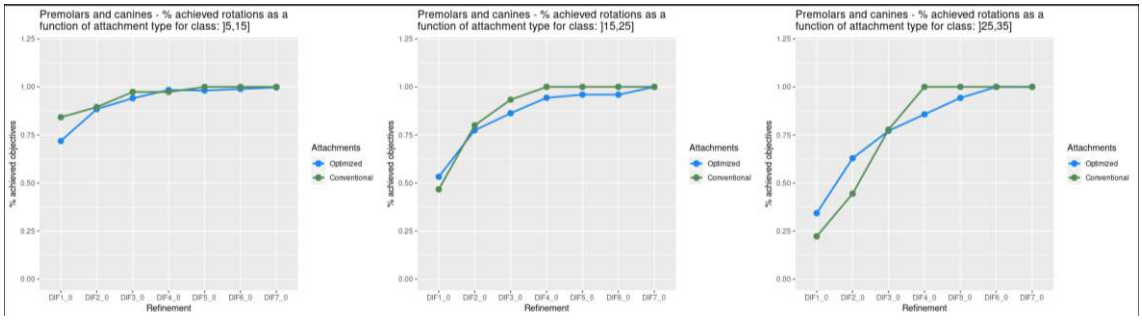


Table 6. The graph shows differences in the amount of solved rotations, through the treatment, between superior teeth and inferior teeth.

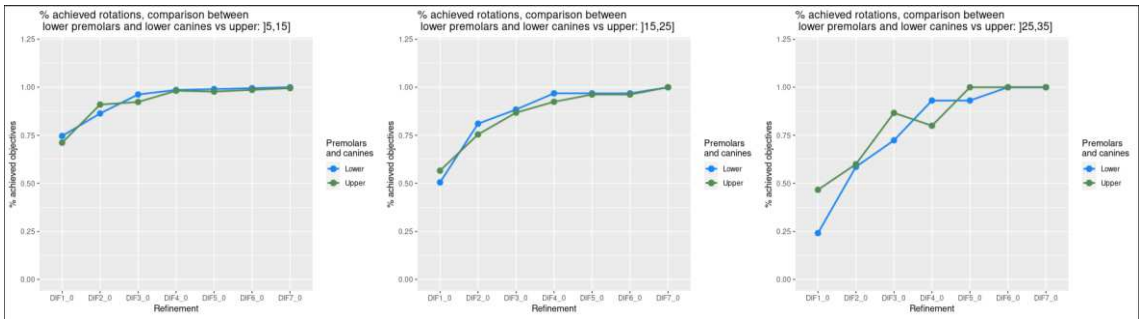
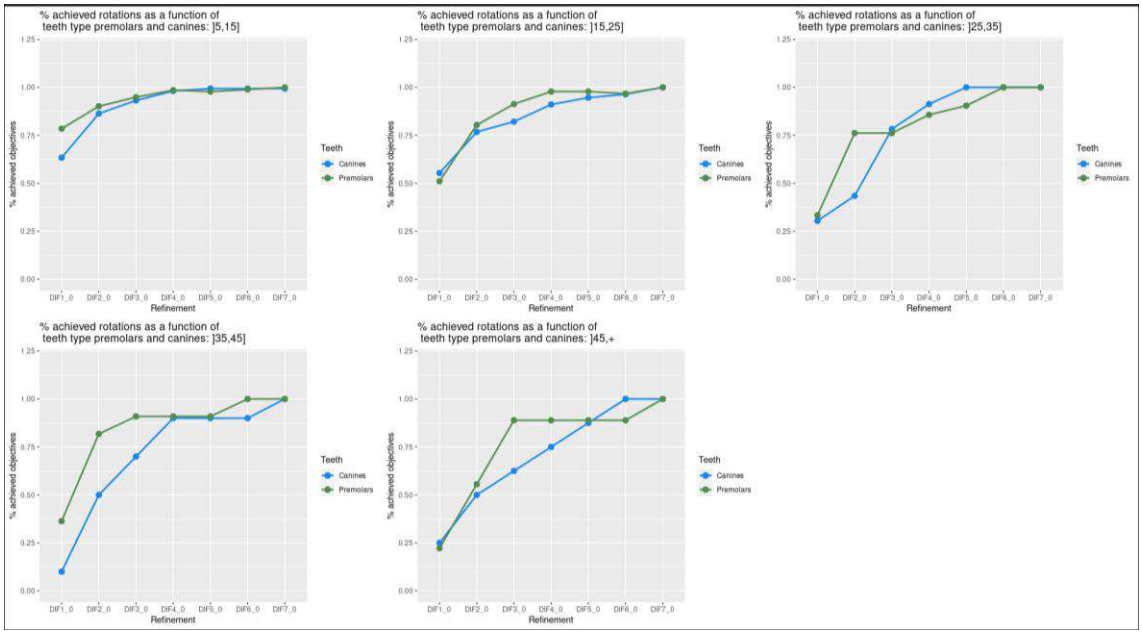


Table 7 represent the amount of solved rotation, through the treatment, between canines (blue) and premolars (green). It appears that in the 25°- 35° group, premolars are corrected faster in the first refinements, but to reach 100% of the correction at the same time of canines. Also, in 35°- 45° and >45°, premolars seem easier to move.

Table 7. Amount of solved rotations, through the treatment, between canines and premolars.



4.DISCUSSION

The aim of this study was to analyze the predictability and efficacy of the derotation of premolars and canines using the Invisalign® System, taking in consideration the use of auxiliaries and the degree of complexity of the movement. Some authors describe the rotation of conoid teeth like premolars and canines as one of the most difficult to perform, as the plastic aligner tends to lose anchorage due to the lack of anatomical undercuts (8)(10). Some studies reflect these statements showing an effectiveness ranging between 29.1% to 49.7% (8)(11). Kravitz *et al.(2008)* tested in their study the influence of interproximal reduction and attachments in the effectiveness of canine de-rotation, and although the highest accuracy was achieved in the group with interproximal reduction, they found no statistical difference between the group with only attachments, the one with interproximal reduction and the one with neither, resulting in a total accuracy of 35.8% (11). Kravitz *et al.(2009)* also shows that for rotations greater than 15° were attempted, the effectiveness of the movement decreases from 35.8% to 14.1% for maxillary canines and from 27.9% to 15.9% for mandibular canines(8). Due to rapid advances in the technology is hard to compare these studies with our, but we can notice an improvement in the efficacy and predictability of the movement even if some precautions still need to be taken. Our study underline how in M3 and M4 some minor rotations that are still present might have been due to multiple variables such as the adaptation of the retainer, poor compliance and/or lack of space for the rotation to occur, as it would have benefited to create space and sequence the movement before attempting the derotation, to minimize complexity of it. 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 with no statistical difference. They also found a decrease in accuracy for movements higher than 15°, from 43.3% to 23.6%, and also a decrease when the planned staging for the de-rotation was higher than 1.5%, from 41.8% to 23.2%(10). In our study, we analyzed if there were any statistical differences between the choice of an optimized attachments over a conventional one, and results were similar for rotations ≤35°. Despite we didn't find a statistical difference, there is a tendency for an increased accuracy of optimized attachments when related to the conventional in the first and second set of aligners, when the magnitude of the rotation is more relevant.

There seems to be no statistically relevant difference in the correction between superior and inferior teeth, but premolars found out to be easier to solve in the beginning of the treatment, probably because canines needs more retention and it takes more time to start the movement in the beginning of the treatment that is related to aligner adaptation. Also, the fact that other vertical movements such as extrusion ≥2.5mm and Intrusion ≥0.5mm could have influenced the effectiveness of the movement. The sudden technological advances pose a risk in comparing the few studies found in the scientific literature, as since 2013 Invisalign® came up with a new polymer for the manufacturing of the aligners (SmartTrack® material) and the software got better. So, the fact that our study found a higher effectiveness in the correction of the movement could be caused by the technological progress, but there's still a lack of scientific evidence showing an improvement in the efficacy of movement related to the new material. We also found that for higher rotations would benefit the use of auxiliaries like elastics and buttons, as we can see from the variations in the inclination of the curves in table 4 for teeth with rotations between 35° and 45°. In this case the clinician, after seeing in M1 that no significant progress was occurring towards the resolution of the rotation, could have decided to use auxiliaries. Some limitations to this study could have been variables like a small sample size of some of the groups with higher de-rotation or lack of cooperation from the patients, even though this last one is reportedly low and not influencing the outcome of the treatment. To this date, we haven't found other articles with the same methodology, and adding the fact there's also a lack of studies about the effectiveness of Invisalign® with these new materials and technologies, such as SmartTrack® material, Smart Stage® technology and Smart Force® feature, this experimental study the first of its kind, hoping that this will help other investigations about other movements and teeth.

5.CONCLUSION

- The derotation of round teeth such as canines and premolars remain a complex movement to accomplish, but recent new technologies and materials might have helped increasing the efficacy and predictability of the movement.
- For higher amounts of derotations, the use of auxiliaries to avoid anchorage loss and help speed up the movement increases the effectiveness.
- Sequencing the movement and creating space before the rotation help decrease the degree of complexity of the derotation
- For de-rotations lower than 35°, it seems to make no difference the use of a conventional attachment over an optimized one, but a tendency seems to appear when the rotation is above 15°.
- It was found no statistically relevant difference in the effectiveness of correction between superior and inferior teeth, but premolars are easier to derotate compared to canines.
- Further research on the topic could help reach a unanimous consensus among the scientific community, that in this moment relies more on single clinical results and expert's opinions

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ANEXES

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Comissão de Ética
Instituto Universitário de Ciências da Saúde
Contacto: 224 157 136
E-mail: carla.ribeiro@cespu.pt

CARTA RESPOSTA

Título do projeto: Efetividade e previsibilidade dos alinhadores invisíveis acerca da derotação pré-molar

Investigador responsável: Luca Mangiaracina

Orientador: Prof. Doutora Teresa Pinho

Nº Registo: 17/CE-IUCS/2020

Parecer:

Exmo(a). Senhor(a),

Em resposta ao pedido efetuado por V. Exa. a esta Comissão de Ética, para emissão de parecer sobre o projeto de investigação supra identificado, somos a informar que, e de acordo com o regulamento, o mesmo recebeu parecer favorável por parte desta Comissão.

Gandra, 9 de março de 2020

Prof. Doutor Jorge Brandão Pereira
Presidente da Comissão de Ética

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