OPEN ACCESS

Scientific Letters

Review

Coronal repercussions of maxillary central incisor torque with clear aligners – Invisalign® system

Ana Catarina Oliveira [1], Ana Sofia Rocha [1], Primavera Sousa-Santos [1] and Teresa Pinho [1,2,*]

[1] UNIPRO, Oral Pathology and Rehabilitation Research Unit, University Institute of Health Sciences-CESPU (IUCS-CESPU), 4585-116 Gandra, Portugal; a26895@alunos.cespu.pt (ACO); a27132@alunos.cespu.pt (ASR); primavera.santos@iucs.cespu.pt (PSS)
[2] IBMC – Molecular and Cellular Biology Institute, i3S – Health Innovation and Research Institute, University of Porto, Porto, Portugal

* Correspondence: teresa.pinho@iucs.cespu.pt

Abstract: Recent years have witnessed a big evolution of clear aligner technology, due to the growing importance of aesthetics and comfort. An adequate coronal torque value has a significant impact on smile aesthetics and on the patient's soft tissue profile. The aim of this systematic review is to evaluate the current knowledge about the efficacy of the maxillary central incisor coronal torque in the Invisalign® system. This study protocol was submitted to the PROSPERO database. Literature research was performed in PubMed, EBSCO Essentials, and Cochrane Library, for articles published from January 2013 to June 2024, using MeSH terms. The literature search identified a total of 281 articles in databases and 3 articles using manual search. Finally, 6 retrospective studies were used for this review work. The ROBINS-I tool was used to assess the methodological quality of the studies. Most studies found significant differences between planned and achieved torque values using the Invisalign® system. A study found that central upper incisor coronal torque was normally underexpressed when the teeth were moving labially and fully or overexpressed when moved lingually.

Keywords: incisor; torque; removable orthodontic treatment; orthodontic movement techniques

Received: 06 May 2024; Accepted: 08 July 2024; Published: 26 July 2024

Introduction

Last years have witnessed a big evolution of clear aligner technology, due to the growing importance of aesthetics and comfort for the patients. The field of Orthodontics has evolved to replace the use of metal brackets with aesthetic brackets, lingual appliances, and clear aligners [1-8].

In 1945, Kesling introduced the first thermoplastic removable appliances with the goal of performing small movements after conventional fixed orthodontic treatment [9]. In 1971, Ponitz suggested the development of removable appliances in a transparent material obtained through the vacuum technique, but with little success [10]. In 1993, Sheridan created the first aligner system (the Essix System) using polypropylene, a sheet of thermoplastic copolyester from Raintree Products [11].

The Invisalign® system, introduced in the 1990s by Align Technology, Inc., is now one of the most used orthodontic systems in the world [3]. It consists of a set of removable polyurethane aligners, made with computer-aided design/computer-aided manufacturing (CAD/CAM) technology, developed for weekly or biweekly changes (depending on the patient's case) [12,13]. Each aligner must be worn between 20 to 22 hours a day [11,14]. Aligner-based orthodontic treatment involves incremental movement of teeth, by use of multiple successive aligners or trays, each of which progressively repositions teeth by small amounts [15].

The aesthetics, the comfort and the ease of cleaning are points in favor of clear aligners when compared to conventional fixed orthodontic appliances [1,5,7,8,16-18]. The limited root movement control, the

limited intermaxillary correction, the little or no control by the operator, the full-time dependence on the patient, with the appliance being removed only for eating and sanitation, are the most relevant disadvantages related to the use of clear aligners [4].

To achieve an efficient movement with the clear aligner's technique, many factors must be considered: aligner characteristics, like the correct shape and position of the attachment; the type of material and thickness of the aligner; the amount of activation in each aligner and the sequence of movements and the associated auxiliary techniques are very important. Auxiliary elements, such as attachments and power ridges, are used to enhance the predictability of specific tooth movements. The strategic arrangement of these auxiliaries in aligners or on the teeth can enhance force delivery [15,19].

Also, patients' characteristics, such as bone density, crown, and root morphology, can affect the behavior of teeth treated orthodontically with the Invisalign® system [17].

According to Andrews, torque represents the third key of occlusion and is one of the most important key factors in orthodontic treatment. Torque movement was described as the tooth movement around the midpoint in a buccolingual direction, so that the crown and root move in opposite directions. Controlling the torque of an upper central incisor requires the creation of effective couples: a tipping force, evoked by reversible deformation of the appliance near the gingival margin, and the resulting force in the opposite direction, produced by movement of the tooth against the inner opposite surface of the appliance near the incisor edge, are necessary [19]. An adequate central upper incisor torque value has a significant impact on smile and on the patient's soft tissue profile [12].

Hahn *et al.* described one of the most challenging factors for the aligner's torque. This author states that, in relation to the intended amount of root movement during torquing, aligners tend to "lift up" and therefore no effective force couple can be established for further root control [19].

To outline a successful orthodontic treatment, the orthodontist needs to know the appropriate therapeutic approaches considering a good diagnosis. With the CAD/CAM system, planning orthodontic treatment with clear aligners is initially performed in a virtual manner [18]. For this reason, the mechanics of orthodontic movement with clear aligners must be defined right from the start, leading to more predictable treatment results.

The aim of this systematic review is to evaluate the current knowledge about the efficacy of the maxillary central upper incisor coronal torque in the Invisalign® system.

Materials and Methods

Review guidelines

We used the review protocol described in Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) recommendations, using the PRISMA checklist and the PRISMA flowchart available at https://www.prisma-statement.org//. This study protocol was submitted to the PROSPERO database (CRD42023430504).

Eligibility criteria

The guiding question was defined according to the Population characteristics, Intervention type, Comparison parameters and Outcomes (PICO) strategy, as presented in Table 1. The search question defined was: "What is the current knowledge about the efficacy of torque movement of maxillary central upper incisors with Invisalign® clear aligners?"

Table 1. PICO strategy.

Patient	Humans with permanent dentition who need interventional torque treatment of maxillary central incisors.
Intervention	Central upper incisor torque treatment with Invisalign® Clear Aligners system.
Comparison	Predicted and achieved maxillary central incisor torque.
Outcome	Efficacy of maxillary central incisor torque with a clear aligner system.
"What is the current knowledge about the efficacy of torque movement of maxillary central upper incisors with Invisalign® clear aligners?"	

The inclusion and exclusion criteria were defined in Table 2.

Table 2. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Articles published from January 2013 to January 2024	Articles in languages other than English
Articles in English language	Articles not available in the database referred in the full text
Availability: full articles that relate to the topic and are not restricted	Abstract does not fit the topic
Articles whose study refers to patients with permanent dentition	Systematic reviews, review articles, dissertations, or theses
Studies performed in humans	Articles referring to patients treated with clear aligners other than the Invisalign® system
Prospective and retrospective clinical studies, community-based trial, randomized clinical trial	Articles referring to patients treated with teeth extraction

Search strategy

Literature research was performed in the PubMed, EBSCO Essentials, and Cochrane Library databases, for articles published from January 2013 to June 2024, using the "incisor", "torque", "orthodontic appliances, removable" and "teeth movement techniques" MeSH terms, which can be found within the titles and abstracts.

The search strategies are detailed in Table 3.

Table 3. Data sources.

Database	Search strategy	Total articles	Selected articles
PubMed	((((("incisor"[MeSH Terms] OR "incisor"[All Fields] OR "incisors"[All Fields] OR "incisor s"[All Fields]) AND "torque"[MeSH Terms]) OR "torque"[All Fields] OR "torques"[All Fields] OR "torqued"[All Fields] OR "torqueing"[All Fields] OR "torquing"[All Fields]) AND ("orthodontic appliances, removable"[MeSH Terms] OR ("orthodontic"[All Fields] AND "appliances"[All Fields] AND "removable"[All Fields]) OR "removable orthodontic appliances"[All Fields] OR ("orthodontic"[All Fields] AND "appliances"[All Fields] AND "removable"[All Fields]) OR "orthodontic appliances removable"[All Fields]) AND (("teeth s"[All Fields] OR "teeths"[All Fields] OR "tooth"[MeSH Terms] OR "tooth"[All Fields] OR "teeth"[All Fields] OR "tooths"[All Fields] OR "tooths"[All Fields]) AND ("movement"[MeSH Terms] OR "movement"[All Fields] OR "movements"[All Fields] OR "movement s"[All Fields]) AND ("methods"[MeSH Terms] OR "methods"[All Fields] OR "technique"[All Fields] OR "methods"[MeSH Subheading] OR "techniques"[All Fields] OR "technique s"[All Fields]))) AND ((ffrft[Filter]) AND (2013:2024[pdat]))	22	0
EBSCO Essentials	AND incisor AllFields AND torque AllFields AND Invisalign AllFields AND accuracy AllFiel (2013-2024 and Full Text Via Editor and Scientific Journals (Peer Reviewed) and Language: English)	223	2
Cochrane Library	Incisor AND torque AND Invisalign OR clear aligner AND teeth movement (Custom Range: 2013-2023)	36	1
Manual Search	AJO-DO; J Clin Orthod; Austras Orthod. J.	-	3

Selection of articles and data collection

The search terms were used to perform an advanced search. Duplicates were manually removed. The titles and abstracts of the potentially relevant articles underwent a preliminary analysis to determine whether they met the purposes of the study. The clinical trials that met the inclusion criteria were completely reviewed and their eligibility was evaluated. The relevant data are presented in Table 4.

Quality assessment of data

The ROBINS-I tool was used to assess the methodological quality of the studies, as all the studies approved in this analysis were non-randomized. Two authors (ACO and ASR) independently evaluated the quality of the selected articles based on seven bias domains: confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, selection of the reported results and overall bias. Two studies were considered to have a minimal risk of bias, making them comparable to well-conducted randomized trials. Most of the studies had a moderate risk of bias. The results are presented in Table 5.

Results

Selection of articles

The bibliographic search identified a total of 281 articles (22 in PubMed, 223 in EBSCO Essentials and 36 in Cochrane Library). We added 3 articles using manual search. Upon analysis, we found 8 duplicate articles. After reading titles and abstracts, 27 articles were selected for further analysis. These were individually reviewed for quality, with 3 of them being selected, adding to the 3 articles that had been manually searched. These data are illustrated in Fig. 1.

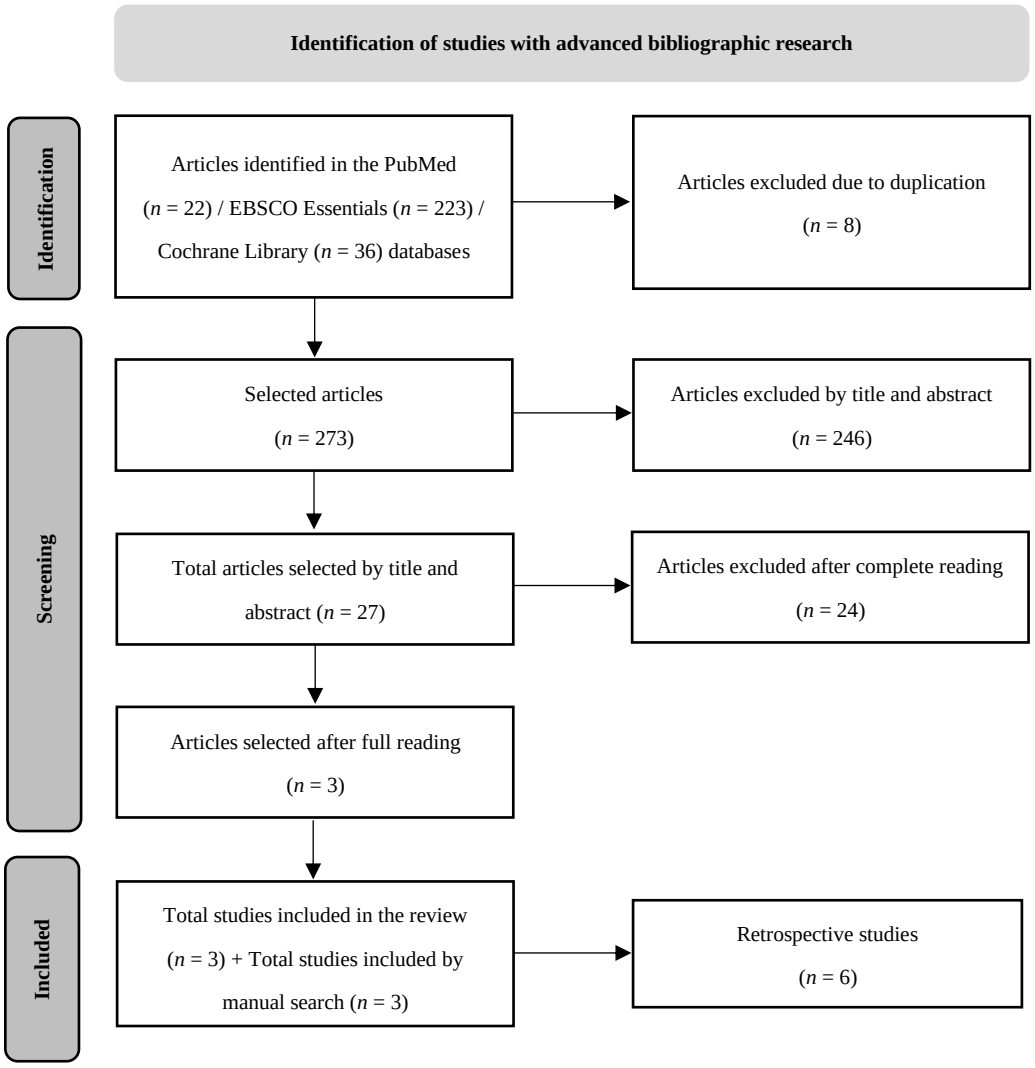

Figure 1. Selection of articles.

Table 4. Data and outcomes from articles.

Author and year of the publication	Title	Aim	Appliances Age range *n* of patients	Measurement	Outcomes
Bowman E *et al.* 2023 [20]	Evaluation of the predicted vs. achieved occlusal outcomes with the Invisalign® appliance: A retrospective investigation of adult patients	Investigate the relationship between occlusal contacts, overbite, transverse expansion and buccolingual inclination of the teeth with reference to the predicted treatment outcomes and achieved outcomes using Invisalign® aligners in mild-to-moderate Class I malocclusions.	Invisalign® 32.7 yrs 33 patients	• The horizontal reference plan using the midpoint of the superior margin of the incisive and interproximal papilla between the maxillary first and second molars; • A virtual long axis of the incisors and a transverse plane on the most distal right and left molars and upper right central incisor were generated; • The angle between the long axis and the plane was the torque measurement.	• The central incisors demonstrated significant differences between predicted and achieved values.
Jiang T *et al.* 2021 [21]	A cone-beam computed tomographic study evaluating the efficacy of incisor movement with clear aligners: Assessment of incisor pure tipping, controlled tipping, translation, and torque	Evaluate the efficacy of different types of incisor movements with clear aligners in the sagittal plane.	Invisalign® Age ≥ 20 yrs (all patients) 69 patients (231 incisors)	• Pretreatment and posttreatment cone-beam computed tomography scans were collected; • Integrated 3D models of the virtual incisor position and the posttreatment incisor position were superimposed over the pretreatment position using Mimics software; • Efficacy was determined by comparing the predicted and achieved incisor movement.	• The efficacy of incisor movement in the sagittal plane using clear aligners varied with designed movement type; labial root movement appeared to be more accurate than the lingual root movement; • Torque was the least predictable movement.
Gaddam R *et al.* 2021 [12]	Reliability of torque expression by the Invisalign® appliance: A retrospective study	Quantify the accuracy of torque expression predicted by ClinCheck® planning associated with Invisalign® treatment compared to clinical outcomes.	Invisalign® 25.5 yrs (SD=3.2 yrs) 40 patients	• Virtual long axis of the incisors and a transverse plane on the most distal right and left molars and upper right central incisor were generated; • The angle between the long axis and the plane was the torque measurement.	• Torque was underexpressed when the teeth were moving labially; • Torque was fully or over-expressed when the teeth moved lingually.
Grünheid T *et al.* 2017 [3]	How accurate is Invisalign® in nonextraction cases? Are predicted tooth positions achieved?	Evaluate the accuracy of the Invisalign® technology in achieving predicted tooth positions with respect to tooth type and direction of tooth movement.	Invisalign® 21.6 yrs (SD=9.8 yrs) 30 patients	• The mesial-buccal cusps of the first molars and the mesial-incisal point of the right central incisor in each arch were used as matching points for initial registration; • A single operator placed a reference coordinate system with the origin of the axes in the center of each tooth of the posttreatment model; • The software automatically generated analogous axes for each corresponding tooth in the virtual treatment model.	• Statistically significant differences between predicted and achieved movements of central upper incisor torque.
Simon M *et al.* 2014 [22]	Treatment outcome and efficacy of an aligner technique – regarding incisor torque, premolar derotation and molar distalization	• Investigate the efficacy of orthodontic treatment using the Invisalign® system; • Analyze the influence of auxiliaries, as well as the staging, on treatment efficacy.	Invisalign® 32.9 yrs (SD=16.3 yrs) 30 patients	• The tooth movement was described by three translations and three rotations around the axes of this coordinate system; • Upper incisor torque was a rotation around the y-axis.	• For maxillary central incisor torque values above 10º, no substantial differences were observed if it was supported with a horizontal ellipsoid attachment or with a Power Ridge.
Castroflorio T *et al.* 2013 [23]	Upper-Incisor Root Control with Invisalign Appliances	Test the efficiency of Align Technology's Power Ridge in controlling the buccolingual inclination of upper incisors.	Invisalign® 26.3 yrs (SD=10.2 yrs) 6 patients	• The gingival and occlusal limits of the facial axis of the clinical crown were identified on a virtual model by tracing the most prominent and center most vertical portion of the labial surface; • A true vertical line was drawn with the Rhinoceros® software; • The angle between these two lines represented the coronal torque.	• It is possible that aligners with Power Ridges may provide better control of the upper incisors than the one that can be achieved with a preadjusted system, at least in some prescriptions.

Table 5. Assessment of risk of bias for expansion outcome using the ROBINS-I tool.

Reference	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall bias
Bowman E *et al.* 2023 [20]	L	M	L	S	M	L	M	M
Jiang T *et al.* 2021 [21]	L	M	L	M	M	M	M	M
Gaddam R *et al.* 2021 [12]	L	M	M	L	L	L	M	L
Grünheid T *et al.* 2017 [3]	L	L	L	L	M	M	M	L
Simon M *et al.* 2014 [22]	L	L	M	S	L	M	M	M
Castroflorio T *et al.* 2013 [23]	L	M	M	S	M	M	M	M

L: low risk of bias; M: moderate risk of bias; S: serious risk of bias.

Discussion

Since the introduction of clear aligners, like the Invisalign® system, in the dental market, the reliability of 3D digital planning has always been a matter of discussion. Recently, clear aligners have been appreciated by patients for their comfort, easy hygiene, and low aesthetic impact [5].

According to the literature, many factors, in addition to the mechanical force system, can affect the expression of incisor torque: rotation correction, because it will not always occur purely along the long axis of the teeth; the pre-existing spacing or crowding, which requires a transverse contraction or expansion that can lead to a corresponding lingually or labially directed force affecting torque expression; the disparity resulting from an underestimation of the mesiodistal width of the teeth by the ClinCheck® plan, which may result in tighter final aligners, possibly contributing to a lingually directed force; and the thickness of the attachments on the buccal surface of the incisors, which may cause a force directed lingually from the lips; predicted movement amount; premolar extraction; canine proclination; molar distalization; mini-implants and age [24,25]. Furthermore, incisors prescribed palatal root movement/labial crown torque will experience an extrusive component of resultant force, which, with the flexible nature of aligners, results in a gap between the tooth and the edge of the aligner on the palatal surface. These are the reasons found by Gaddam *et al.* for their conclusions. They found an underexpression of buccal crown torque and a normoexpression or overexpression of lingual torque [12].

The literature is very controversial. Although some past studies demonstrate no significant differences between planned and achieved values regarding maxillary central upper incisor torque, others found statistically significant differences [3,6,17,20].

Jiang *et al.* found that the least accurate movement was torque (35.21%). This finding suggested that clear aligners share the same biomechanical principle of tooth movement as the other orthodontic appliances. Nevertheless, the material properties of clear aligners might probably be responsible for their inability to apply root control [21].

Grünheid *et al.*, in their study, used a sample of thirty patients; however, they did not subdivide the sample into retroinclination and proclination, like Gaddam *et al.* [3,12]. Bowman *et al.*, with a sample of thirty-three patients, concluded that the central incisors demonstrated significant differences between predicted and achieved values, but the authors included adults only in their study [20].

The study made by Gaddam *et al.* was the only one that carried out the sample division into retroclination and proclination [12].

Using the Geomagic® Control X™ software and creating a virtual long axis of the incisor and a transverse plane on the most distal right and left molars and upper right central incisor, Gaddam *et al.* concluded that the difference between predicted and achieved torque was statistically significant ($p < 0.001$) in the group corresponding to buccal crown (proinclination) torque for the maxillary central incisor. The subgroup corresponding to the lingual/palatal crown (retroinclination) torque did not show a statistically significant torque differential ($p > 0.05$). Then, Gaddam *et al.* found that labial crown torque (lingual root torque) was less predictable [12]. Like Gaddam *et al.*, Jiang *et al.* concluded that labial root movement appears to be more accurate than the lingual root movement [21].

Chisari *et al.*, in their study, found a relationship between age, sex, root length, bone levels, and bone quality on orthodontic tooth movement [26].

In the study by Castroflorio *et al.*, it was concluded that it is possible that aligners with Power Ridges may provide better control of the upper incisors than the one that can be achieved with a preadjusted system, at least in some prescriptions [20]. Also, the use of horizontal ellipsoid attachments can help achieving the planned torque values [22].

The incorporation of cone beam computer tomography (CBCT) in the intraoral scanner by dental superimposition based on stable anatomical landmarks has been an asset in the planning of orthodontic treatments. The use of 3D with incorporation of CBCT allows assessing, in addition to the coronal repercussions of the torque movement, changes in the root, determining whether the planned root movements were fully achieved [21].

We consider that the small sample size of most studies is one of the limitations. Regarding the sampling subdivision into retroinclination and proinclination, another limitation is the smaller number of studies that performed this division, with only Gaddam *et al.* having done it. In orthodontic treatments, other simultaneous tooth movements may lead to difficulties in achieving the planned torque value (rotations and extrusions/intrusions, for example).

Two more articles on this subject were found through the search expression used on the PubMed platform, but they were excluded because: i) they did not use the Invisalign® technology, but Nuvola® (Tepedino *et al.* 2018); ii) they evaluated cases of premolar extractions (Dai *et al.* 2019). The scientific literature that supported this study proved to be another of the difficulties found in the preparation of this work, namely the diversity of methodologies identified.

According to recent reports, a significant number of patients using Invisalign® aligners (70-80%) would require additional aligners, which suggests that the accuracy of ClinCheck® software treatment planning is low. This can be due to the practitioner's inexperience with the technique, the software, or a lack of patient compliance [27]. Therefore, it is important for orthodontists to know the limitations of clear aligners, anticipating the possible need for additional aligners. Furthermore, this systematic review aims to motivate the search for tools to improve orthodontic results with invisible aligners.

The results of the study allowed us to conclude that this is a controversial topic. We found studies that demonstrated significant differences between predicted and achieved values and studies that failed to demonstrate differences. Most studies found significant differences between planned and achieved torque values using the Invisalign® system. A study found that central upper incisor coronal torque was, normally, underexpressed when the teeth were moving labially and fully or overexpressed when moved lingually.

Acknowledgments

This work was funded by Cooperativa de Ensino Superior Politécnico e Universitário (CESPU): project AlignAgen-GI2-CESPU-2022. We are grateful for the availability and cooperation of the Department of Dental Sciences, University Institute of Health Sciences (IUCS), CESPU.

Author Contributions

ACO planned the overall design, conceived and designed the work, acquired, analyzed, and interpreted the data, and was the main author of the manuscript. ASR substantially revised the manuscript. PSS revised the manuscript. TP was responsible for the idea for the study, conceived and designed the work, analyzed the data, drafted and substantially revised the manuscript. All authors read and approved the final manuscript.

Conflicts of interest

The authors declare no competing interests.

References

1. Long, H.; Wu, Z.; Yan, X.; Wang, Q.; Liu, L.; Wang, Y.; Jian, F.; Liao, L.; Li, X.; Lai, W. An objective system for appraising clear aligner treatment difficulty: clear aligner treatment complexity assessment tool (CAT-CAT). *BMC Oral Health* **2020**, *20*, 312, doi:10.1186/s12903-020-01300-6.
2. Cheng, Y.; Gao, J.; Fang, S.; Wang, W.; Ma, Y.; Jin, Z. Torque movement of the upper anterior teeth using a clear aligner in cases of extraction: a finite element study. *Prog Orthod* **2022**, *23*, 26, doi:10.1186/s40510-022-00421-8.
3. Grunheid, T.; Loh, C.; Larson, B.E. How accurate is Invisalign in nonextraction cases? Are predicted tooth positions achieved? *Angle Orthod* **2017**, *87*, 809-815, doi:10.2319/022717-147.1.
4. Pithon, M.M.; Baiao, F.C.S.; Sant Anna, L.; Paranhos, L.R.; Cople Maia, L. Assessment of the effectiveness of invisible aligners compared with conventional appliance in aesthetic and functional orthodontic treatment: A systematic review. *J Investig Clin Dent* **2019**, *10*, e12455, doi:10.1111/jicd.12455.
5. Bilello, G.; Fazio, M.; Amato, E.; Crivello, L.; Galvano, A.; Curro, G. Accuracy evaluation of orthodontic movements with aligners: a prospective observational study. *Prog Orthod* **2022**, *23*, 12, doi:10.1186/s40510-022-00406-7.

6. Dai, F.F.; Xu, T.M.; Shu, G. Comparison of achieved and predicted tooth movement of maxillary first molars and central incisors: First premolar extraction treatment with Invisalign. *Angle Orthod* **2019**, *89*, 679-687, doi:10.2319/090418-646.1.
7. Cheng, Y.; Liu, X.; Chen, X.; Li, X.; Fang, S.; Wang, W.; Ma, Y.; Jin, Z. The three-dimensional displacement tendency of teeth depending on incisor torque compensation with clear aligners of different thicknesses in cases of extraction: a finite element study. *BMC Oral Health* **2022**, *22*, 499, doi:10.1186/s12903-022-02521-7.
8. Liu, L.; Zhan, Q.; Zhou, J.; Kuang, Q.; Yan, X.; Zhang, X.; Shan, Y.; Li, X.; Lai, W.; Long, H. Effectiveness of an anterior mini-screw in achieving incisor intrusion and palatal root torque for anterior retraction with clear aligners. *Angle Orthod* **2021**, *91*, 794-803, doi:10.2319/120420-982.1.
9. Kesling, H.D. The philosophy of the tooth positioning appliance. *Am J Orthod Oral Surg* **1945**, *31*, 297-304, doi:10.1016/0096-6347(45)90101-3.
10. Ponitz, R.J. Invisible retainers. *Am J Orthod* **1971**, *59*, 266-272, doi:10.1016/0002-9416(71)90099-6.
11. Bichu, Y.M.; Alwafi, A.; Liu, X.; Andrews, J.; Ludwig, B.; Bichu, A.Y.; Zou, B. Advances in orthodontic clear aligner materials. *Bioact Mater* **2023**, *22*, 384-403, doi:10.1016/j.bioactmat.2022.10.006.
12. Gaddam, R.; Freer, E.; Kerr, B.; Weir, T. Reliability of torque expression by the Invisalign® appliance: A retrospective study. *Aust Orthod J* **2021**, *37*, 3-13, doi: 10.21307/aoj-2021-001.
13. Sabbagh, H.; Heger, S.M.; Stocker, T.; Baumert, U.; Wichelhaus, A.; Hoffmann, L. Accuracy of 3D Tooth Movements in the Fabrication of Manual Setup Models for Aligner Therapy. *Materials (Basel)* **2022**, *15*, doi:10.3390/ma15113853.
14. Al-Nadawi, M.; Kravitz, N.D.; Hansa, I.; Makki, L.; Ferguson, D.J.; Vaid, N.R. Effect of clear aligner wear protocol on the efficacy of tooth movement. *Angle Orthod* **2021**, *91*, 157-163, doi:10.2319/071520-630.1.
15. Upadhyay, M.; Arqub, S.A. Biomechanics of clear aligners: hidden truths & first principles. *J World Fed Orthod* **2022**, *11*, 12-21, doi:10.1016/j.ejwf.2021.11.002.
16. Ke, Y.; Zhu, Y.; Zhu, M. A comparison of treatment effectiveness between clear aligner and fixed appliance therapies. *BMC Oral Health* **2019**, *19*, 24, doi:10.1186/s12903-018-0695-z.
17. Tepedino, M.; Paoloni, V.; Cozza, P.; Chimenti, C. Movement of anterior teeth using clear aligners: a three-dimensional, retrospective evaluation. *Prog Orthod* **2018**, *19*, 9, doi:10.1186/s40510-018-0207-3.
18. Goncalves, A.; Collard, A.; Monteiro, F.; Matos, D.; Carvalho, O.; Azevedo, R.; Silva, F.S.; Pinho, T. Accuracy of Invisalign((R)) on Upper Incisors: A Systematic Review. *Turk J Orthod* **2023**, *36*, 126-133, doi:10.4274/TurkJOrthod.2022.2021.0254.
19. Hahn, W.; Zapf, A.; Dathe, H.; Fialka-Fricke, J.; Fricke-Zech, S.; Gruber, R.; Kubein-Meesenburg, D.; Sadat-Khonsari, R. Torquing an upper central incisor with aligners--acting forces and biomechanical principles. *Eur J Orthod* **2010**, *32*, 607-613, doi:10.1093/ejo/cjq007.
20. Bowman, E.; Bowman, P.; Weir, T.; Dreyer, C.W.; Meade, M.J. Evaluation of the predicted vs. achieved occlusal outcomes with the Invisalign(R) appliance: A retrospective investigation of adult patients. *Int Orthod* **2023**, *21*, 100746, doi:10.1016/j.ortho.2023.100746.
21. Jiang, T.; Jiang, Y.N.; Chu, F.T.; Lu, P.J.; Tang, G.H. A cone-beam computed tomographic study evaluating the efficacy of incisor movement with clear aligners: Assessment of incisor pure tipping, controlled tipping, translation, and torque. *Am J Orthod Dentofacial Orthop* **2021**, *159*, 635-643, doi:10.1016/j.ajodo.2019.11.025.
22. Simon, M.; Keilig, L.; Schwarze, J.; Jung, B.A.; Bourauel, C. Treatment outcome and efficacy of an aligner technique--regarding incisor torque, premolar derotation and molar distalization. *BMC Oral Health* **2014**, *14*, 68, doi:10.1186/1472-6831-14-68.
23. Castroflorio, T.; Garino, F.; Lazzaro, A.; Debernardi, C. Upper-incisor root control with Invisalign appliances. *J Clin Orthod* **2013**, *47*, 346-351; quiz 387.
24. Shailendran, A.; Weir, T.; Freer, E.; Kerr, B. Accuracy and reliability of tooth widths and Bolton ratios measured by ClinCheck Pro. *Am J Orthod Dentofacial Orthop* **2022**, *161*, 65-73, doi:10.1016/j.ajodo.2020.06.048.
25. Yan, X.; Zhang, X.; Ren, L.; Yang, Y.; Wang, Q.; Gao, Y.; Jiang, Q.; Jian, F.; Long, H.; Lai, W. Effectiveness of clear aligners in achieving proclination and intrusion of incisors among Class II division 2 patients: a multivariate analysis. *Prog Orthod* **2023**, *24*, 12, doi:10.1186/s40510-023-00463-6.

26. Chisari, J.R.; McGorray, S.P.; Nair, M.; Wheeler, T.T. Variables affecting orthodontic tooth movement with clear aligners. *Am J Orthod Dentofacial Orthop* **2014**, *145*, S82-91, doi:10.1016/j.ajodo.2013.10.022.

27. Kravitz, N.D.; Kusnoto, B.; BeGole, E.; Obrez, A.; Agran, B. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. *Am J Orthod Dentofacial Orthop* **2009**, *135*, 27-35, doi:10.1016/j.ajodo.2007.05.018.