

The accuracy of biomechanical mechanisms for dental deep bite correction using the Invisalign system

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Objective: To evaluate the accuracy of the Invisalign appliance in correcting an anterior deep bite in adults and to compare different mechanisms of bite opening.

Materials and methods: This retrospective study included 25 patients (mean age 32.28 years) who presented with a moderate overbite (Group 1, with an overbite ranging from 3.5 mm to 5 mm) or a severe overbite (Group 2, with an overbite ≥ 5 mm), treated by the same operator using the Invisalign appliance.

Digital models generated for the ClinCheck process were analysed at the initial (T0), planned (ST1), and clinically achieved (ET1) stages using Geomagic Control X software (3D Systems, Rock Hill, SC, USA) to measure overbite correction. The accuracy and mechanisms of deep bite correction (proclination and intrusion of the incisors, posterior tooth extrusion) were assessed. Statistical analysis was performed using R 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria).

Results: Significant differences were found between the ST1 and ET1 stages of overbite correction in both groups ($P < 0.01$). Group 1 showed the highest mean accuracy (51.35%) with a mean difference of 1.15 mm between ST1 and ET1. Group 2 had the lowest mean accuracy (41.56%) with a mean difference of 2.11 mm. No significant differences in mean accuracy were found between the groups or between the mechanisms of overbite correction ($P > 0.05$).

Conclusion: The Invisalign appliance shows significant inaccuracy between the ClinCheck simulation and the clinical outcome in correcting moderate and severe deep bites in adults. There was similar predictability between the different bite opening mechanisms.

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Introduction

The number of patients seeking orthodontic treatment has significantly increased in recent years and meeting aesthetic needs remains a primary objective, especially for adult patients.¹

The recent advent of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) technology has enabled the simulation of dental movements with a pre-visualisation of individualised treatment outcomes, and the production of customised removable transparent aligners.²

The first clear aligner system based on 3D technology for treatment planning and fabrication was the Invisalign appliance (Align Technology, Santa Clara, CA, USA). Since 1997, the Invisalign system has been introduced into routine clinical practice as a viable and aesthetic alternative to traditional fixed appliance therapy.^{3,4}

Significant improvements have been introduced in the Invisalign system,⁴ starting in 2013 with a change in the aligner material (SmartTrack) and continuing through 2014 with further advancements in aligner design (the introduction of precision bite ramps) and updates of the ClinCheck software (Invisalign G8).^{1,5}

Although these advancements have enhanced the efficiency of treatment biomechanics,⁶ the correction of a deep overbite remains challenging and controversial. Even if the amount of tooth movement can be virtually simulated by the ClinCheck software, the predicted plans do not exactly correspond to the patient's occlusion at the end of active treatment.⁶

The planned bite opening presented by the ClinCheck software overestimates the clinically achieved overbite correction.^{5,6} Blundell et al.^{5,6} found that the prescribed overbite reduction was achieved for only 39.2% of patients using Smart Track material without bite ramps, for 43.4% using Smart Track material with bite ramps, and for 55.1% using EX30 material without bite ramps. Lower values were found by Shahabuddin et al.⁷ who reported an average of 33% accuracy in overbite correction using the aligners made from SmartTrack material.

Krieger et al.⁸ also reported that vertical movements were more difficult to achieve using clear aligners compared to sagittal or transverse movements and that an anterior overbite was the most difficult feature to predict and correct because of the challenge of achieving the digitally programmed outcome.^{9–11}

Conventionally, the main correction mechanisms for deep bite include the extrusion of the posterior segments, the intrusion of anterior teeth, a combination of posterior extrusion and anterior intrusion, or the proclination of the incisors.^{6,7,12}

Although many studies have focused on the achievement of treatment outcomes,^{1,13,14} the accuracy of the biomechanical mechanisms by which aligners correct a deep bite has not been thoroughly

investigated. In 2009, Kravitz et al.⁹ reported an overall mean accuracy of 41% for the Invisalign system and, despite significant technological improvements, this percentage has only increased to 50%, with posterior extrusion and anterior intrusion still identified as the most critical movements.¹⁵

The literature has reported that some movements are more predictable compared to others, when using a clear aligner system.¹⁵ Several studies have indicated that tooth extrusion using aligners appears to be more complicated compared to other mechanics for deep bite correction, as the presence of plastic material between the posterior teeth can cause posterior tooth intrusion, thereby worsening an overbite.^{6,16} According to previous research,^{9,17} a mean accuracy of 30% has been reported for extrusive movement, which has increased up to 45.9% in recent years.¹⁵

Additionally, further studies have reported that the correction of a deep bite using the Invisalign appliance is mainly due to the proclination of the mandibular incisors, along with minimal intrusion of the upper incisors.^{17–19}

Grunheid et al.²⁰ reported that aligner treatment was not able to completely achieve the predicted anterior intrusion, with an overall correction ranging from 0.75 to 1.50 mm. Similarly, Khosravi et al.¹⁹ found an average correction ranging from 0.3 mm for a normal overbite up to 1.5 mm in deep bite cases, even though this correction was mostly due to incisor proclination.

Therefore, due to the lack of evidence regarding certain intended movements during aligner treatment, the aim of the present study was to evaluate the overall accuracy of the Invisalign system in anterior overbite correction and to compare the predictability of different biomechanical strategies for bite opening in adult patients presenting with a moderate to severe deep bite.

Material and methods

Study design, eligibility criteria and study setting

This retrospective study investigated an initial sample of 347 adult patients who had received Invisalign® (Align Technology, Santa Clara, CA, USA) clear aligner treatment. The sample was obtained from a single experienced orthodontist within the discipline of Orthodontics, Department of Dentistry,

Table I. Sample distribution

Gender	Frequency	Percentage (%)	Mean Age (min-max)
Females	13	52	33.52 y (28.12–38.94)
Males	12	48	29.62 y (20.61–38.64)
Total	25	100	32.28 y (27.55–37.01)

Y, year.

University of San Raffaele (Milan, Italy). All research procedures adhered to the Declaration of Helsinki, and each patient signed a written consent form agreeing to the protocol of the present study.

The patients were instructed to wear their aligners for 22 hours per day and, considering that compliance was critical for the execution of the study, compliance was verbally confirmed at each appointment.¹⁵ All patients met the following inclusion criteria: (1) age greater than 18 years to exclude any growth changes; (2) Invisalign appliance treatment of both arches; (3) in the permanent dentition, with the presence of the first and second molars; (4) a Class I malocclusion (Angle's classification); (5) overbite > 3.5 mm; (6) non-extraction treatment; (7) a minimum of 14 aligners, without mid-course correction nor additional aligners; (8) good compliance.

The main exclusion criteria were: (1) the use of bite ramps, elastics (vertical or cross), or auxiliaries; (2) low-quality scans; (3) interproximal enamel reduction; (4) orthognathic patients; (5) dental restorations before the refinement scan; (6) patients with an overbite > 8mm.

According to the eligibility criteria, the final sample was composed of 25 adult patients, of whom 13 were females and 12 were males (Table I).

The enrolled patients were divided into two groups, according to the pre-treatment overbite:

Group 1 (a moderately deep bite): 3.5 mm ≤ overbite ≤ 5 mm.

Group 2 (a severely deep bite): 5 mm ≤ overbite ≤ 8 mm.

Pre-treatment digital scans were acquired using a TRIOS 3 (3Shape, Copenhagen, Denmark) colour

intraoral scanner, and sent to Align Technology for the ClinCheck planning. To standardise the overbite correction protocol, a vertical movement of 0.20 + -0.05 mm was planned per stage. For all patients, a normal overbite was programmed at the final stage of the ClinCheck process without overcorrection.

All patients had standardised rectangular horizontal attachments (measuring 3 mm in width and 1.5 mm in height and without a bevelled design) positioned in the centre of the clinical crown of the premolars and first molars.

Digital models were exported from the ClinCheck program as stereolithography (.stl) files. The files included the initial and final models from the first ClinCheck process, representing the “initial” (T0) and “simulated” (ST1) overbite. Additionally, the files included the initial models from the refinement ClinCheck assessment, showing the “effective” (ET1) overbite clinically achieved after the first round of aligners or before a refinement phase.

Outcome measures

Each model was imported into Geomagic Control X software (version 2017.0.3; 3D Systems, Rock Hill, SC, USA). The measurements of overbite depth were performed by a single experienced orthodontist (GF) according to the methodology previously proposed by Blundell et al.^{5,6}

T0, ST1 and ET1 models were oriented to a horizontal occlusal reference plane adapted from Grünheid et al.²⁰ and defined by the midpoint of the superior margin of the incisive papilla and the interproximal papilla between the upper first and second molars.

Following model alignment, the overbite was measured by considering the greatest vertical distance between the edges of the upper and lower incisors (central or lateral) according to the American Board of Orthodontics grading system.^{5,6}

The following measurements were calculated:

- $T0-ST1$ = simulated overbite correction (T0 minus ST1).
- $T0-ET1$ = effective overbite correction (T0 minus ET1).
- $ST1-ET1$ = non-achieved overbite correction (ST1 minus ET1).

Table II. Descriptive statistics of the overbite values for the overall sample

	Mean	SD	95% CI
T0 OVB (mm)	4.66	0.86	4.32–4.99
ST1 OVB (mm)	1.91	0.71	1.63–2.19
ET1 OVB (mm)1	3.34	0.85	3.00–3.67
ST1-T0 OVB (mm)	2.74	0.81	2.42–3.06
ET1-T0 OVB (mm)	1.32	0.58	1.09–1.55
Accuracy (%)	48.61	19.22	41.07–56.14

ET1 OVB, post-treatment overbite; ET1-T0 OVB, clinically achieved overbite correction; ST1 OVB, overbite correction simulated on Clincheck; ST1-T0 OVB, predicted overbite correction; T0 OVB, pre-treatment overbite.

The accuracy was calculated as a percentage (%) using the following equation:

$$\text{Accuracy} = (\text{T0-ET1}/\text{T0-ST1}) \times 100.$$

For each group, the mechanisms of deep bite correction and the influence on the accuracy of overbite correction were also analysed, which included the intrusion of the upper (U1) and lower (L1) incisors, upper and lower posterior tooth extrusion, and U1/L1 proclination.

In addition, the influence of the number of attachments placed on the lower premolars and molars on overall accuracy, was evaluated.

Statistical analysis

Two weeks after the initial measurements, the same experienced operator repeated 40 measurements on randomly selected models. Intra-examiner reliability was assessed using the Intraclass Correlation Coefficient (ICC; model = 2-way mixed effects, type = single measurement, definition = absolute agreement).

Statistical analysis was performed using R software (version 4.1.0; R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were used to summarise the mean movements of the overall sample. To assess any significant changes in overbite correction, a paired *t* test was conducted. An analysis of variance (ANOVA) test was performed to identify any significant differences in the accuracy of overbite correction. A Spearman correlation coefficient was used to determine whether larger predicted overbite corrections were correlated with

lower prediction accuracy. $P < 0.05$ was considered statistically significant.

Results

A total of 25 patients were analysed (18 with a deep bite, 7 with a severely deep bite). The ICC test showed an excellent correlation of 0.997 (ranging from 0.992 to 0.999), for intra-observer reliability.

The sample distribution is presented in Table I.

Descriptive statistics of the overbite values for the overall study population are shown in Table II.

Statistically significant differences were reported between T0 and ST1 overbite ($p < 0.001$) for both groups (Table III).

A statistically significant difference was found between ST1 and ET1 (Table IV). The larger mean accuracy ($51.35 \pm 21\%$) was observed in the group with a moderate overbite, resulting in a mean difference of 1.15 mm (± 0.6) between the ST1 and ET1 overbite. The lowest mean accuracy was found in the group with a severe overbite, in which 41.56% (± 10.81) of the predicted movement was achieved, with a mean difference of 2.11 mm (± 0.4) between the ST1 and ET1 correction.

The overall Spearman correlation coefficient showed that there was a relationship between the magnitude of the planned overbite correction and the accuracy of the prediction ($p = -0.07$). However, this correlation was not statistically significant ($p = 0.74$) (Table V). A statistically significant difference ($p < 0.05$) was reported in both T0 and ST1 overbite correction between the groups of moderate and severely deep

Table III. Comparison between pre-treatment overbite (T0) and simulated overbite (ST1) planned on the ClinCheck

Groups	T0 OVB (mm)	ST1 OVB (mm)	P value
	Mean $\pm$ SD (95% CI)	Mean $\pm$ SD (95% CI)	
Moderate	4.27 $\pm$ 0.42 (4.07–4.46)	2.39 $\pm$ 0.63 (2.10–2.68)	<0.001 **
Severe	5.67 $\pm$ 0.88 (5.02–6.32)	3.64 $\pm$ 0.47 (3.30–3.99)	<0.001 **

* $p < 0.05$, ** $p < 0.01$, n.s. $p > 0.05$.

Table IV. Accuracy of the overbite correction

Groups	TO-ST1 OVB (mm)	TO-ET1 OVB (mm)	ST1-ET1 (mm)	P value	Accuracy (%)
	Mean $\pm$ SD (95% CI)	Mean $\pm$ SD (95% CI)	Mean $\pm$ SD (95% CI)		Mean $\pm$ SD (95% CI)
Moderate	2.39 $\pm$ 0.63 (2.10–2.68)	1.24 $\pm$ 0.59 (0.97–1.52)	1.15 $\pm$ 0.6 (0.87–1.43)	<0.001**	51.35 $\pm$ 21 (41.65–61.05)
Severe	3.64 $\pm$ 0.47 (3.30–3.99)	1.53 $\pm$ 0.5 (1.16–1.90)	2.11 $\pm$ 0.4 (1.82–2.41)	<0.001**	41.56 $\pm$ 10.81 (33.55–49.05)

* $p < 0.05$, ** $p < 0.01$, n.s. $p > 0.05$.

bite (Table VI). However, no statistically significant differences were found in the accuracy of anterior overbite correction between the two groups.

Considering the correlation between the planned bite opening mechanisms described in the ClinCheck program and the prediction accuracy, no statistically significant differences were shown for any of the mechanisms ($p > 0.05$) (Table VII). However, the highest prediction accuracy was achieved in the lower posterior tooth extrusion group (58.25% $\pm$ 22.06), while the upper incisor intrusion group had the lowest prediction accuracy value (46.57% $\pm$ 17.95).

No significance was found upon comparing the number of bite opening methods and the achievement of overbite correction ($p > 0.05$) (Table VIII), as well as in the number of attachments on the lower premolars and molars (Table IX).

Discussion

Involving the initial series of aligners, the aim of the present study was to assess the accuracy of the Invisalign appliance in deep bite correction using different mechanisms of bite opening, and to compare the planned overbite simulated on ClinCheck to the effective clinical overbite achieved at the end of treatment.

Clinically, it is useful to minimise the need for additional aligners and to identify the most predictable bite opening mechanism to improve the outcome of the planned tooth movement.

Adult patients with fully erupted permanent teeth were enrolled in the present study to avoid vertical changes due to physiological growth or dental eruption.²¹ Similarly, the use of bite ramps, elastics, or auxiliaries was excluded to avoid their possible bite opening effects. Cases treated by a single Invisalign-experienced

specialist were selected to avoid intra-operator bias variables. Additionally, rectangular horizontal attachments, standardised in the centre of the clinical crown, were used to minimise the risk of bias due to variability in attachment shape and position. In support, a recent review by Nucera et al.²² on the effects of attachments for achieving orthodontic movements with aligners, emphasised that evidence regarding the optimal shape and position of attachments is still lacking, especially for challenging movements like intrusion or extrusion.

Although continual improvements in the Invisalign® system have occurred over the years,^{1,23} the clinical expression of overbite correction remains a controversial topic.⁷

Clinical evidence supports the poor predictability of aligners in correcting a deep bite.^{5–7} In the present findings, a large discrepancy in overbite correction was found between ST1 (2.74 $\pm$ 0.81 mm) and ET1 (1.32 $\pm$ 0.58 mm), with an overall accuracy of 48.61% after the initial set of aligners.

In patients with a moderate or a severely deep bite, significant differences were found between the simulated and the achieved overbite correction, reporting a mean accuracy of 51.35% ($\pm$ 21.0) and 41.56% ($\pm$ 10.81), respectively. Despite the high

Table V. Spearman's correlation coefficient between the predicted overbite correction and the prediction accuracy

	Spearman's correlation coefficient	P-value
Moderate	0.08	0.76
Severe	0.29	0.53
Total	-0.07	0.74

* $p < 0.05$, ** $p < 0.01$, n.s. $p > 0.05$.

Table VI. Association between overbite severity and accuracy

	Moderate	Severe	P-value
	Mean $\pm$ SD (95% CI)	Mean $\pm$ SD (95% CI)	
T0 OVB	4.27 $\pm$ 0.42 (4.07–4.46)	5.67 $\pm$ 0.88 (5.02–6.32)	0.023*
T0-ST1 OVB	2.39 $\pm$ 0.63 (2.10–2.68)	3.64 $\pm$ 0.47 (3.30–3.99)	0.046*
T0-ET1 OVB	1.24 $\pm$ 0.59 (0.97–1.52)	1.53 $\pm$ 0.5 (1.16–1.90)	0.61
Accuracy	51.35 $\pm$ 21 (41.65–61.05)	41.56 $\pm$ 10.81 (33.55–49.05)	0.61

* $p < 0.05$, ** $p < 0.01$, n.s. $p > 0.05$.

Table VII. Correlation between the nature of planned bite opening mechanisms in the ClinCheck and prediction accuracy

		N	Mean accuracy (%)	SD	CI 95%	P-value
U1 intrusion	Present	19	46.57	17.95	38.50– 54.64	0.66
	Absent	6	55.07	21.55	37.82– 72.32	
L1 intrusion	Present	24	47.78	19.18	40.11– 55.46	/
	Absent	1	68.42	/	68.42– 68.42	
Upper posterior extrusion	Present	10	53.04	18.83	41.37– 64.71	0.7
	Absent	15	45.66	18.92	36.08– 55.23	
Lower posterior extrusion	Present	10	58.25	22.06	44.57– 71.92	0.37
	Absent	15	42.18	13.72	35.24– 49.13	
U1 proclination	Present	8	53.79	17.94	41.35– 66.22	0.69
	Absent	17	46.17	19.33	36.99– 55.36	
L1 proclination	Present	17	52.08	20.56	42.30– 61.85	0.57
	Absent	8	41.24	13.31	32.02– 50.47	

* $p < 0.05$, ** $p < 0.01$, n.s. $p > 0.05$.

L1, lower incisors; U1, upper incisors..

Table VIII. Correlation between the number of opening bite mechanisms and the overbite correction

	1 or 2 (N = 4)	3 or 4 (N = 20)	5 or 6 (N = 1)	P-value
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
ST1-T0 OVB(mm)	1.90 $\pm$ 0.93	2.94 $\pm$ 0.73	2.3	0.057
ET1-T0 OVB (mm)	0.88 $\pm$ 0.62	1.38 $\pm$ 0.55	2.1	0.125

* $p < 0.05$; ** $p < 0.01$; n.s. $p > 0.05$.

Table IX. Mean overbite correction and frequency of the attachments number on lower premolars and molars

	2 att (N = 1)	4 att (N = 3)	5 att (N = 1)	6 att (N = 16)	7 att (N = 1)	8 att (N = 3)	P-value
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
T0-ST1	2.20 /	2.60 $\pm$ 0.65	2.20 /	2.68 $\pm$ 0.84	3.90 /	3.23 $\pm$ 1.14	0.54
T0-ET1	1.10 /	1.40 $\pm$ 0.48	0.70 /	1.26 $\pm$ 0.62	1.20 /	1.87 $\pm$ 0.68	0.56

* $p < 0.05$, ** $p < 0.01$, n.s. $p > 0.05$.

value of the standard deviation, this outcome may be primarily attributed to the different mechanisms involved in correcting the deep bite, which may have significantly affected the variability of the obtained movements due to their complexity, as well as individual variability. To address this issue, the data from the different types of programmed movements were separately analysed to assess whether there were significant differences between the various subgroups (Table VII). This ensured that the variability was associated with the different types of movement rather than methodological errors.

Although the present findings highlight a significant discrepancy between the planned and the achieved overbite changes using the Invisalign system, these values were higher than those previously reported.⁵⁻⁷ Shahabuddin *et al.*⁷ noted a mean overbite correction of 33% using Smart Track material appliances and bite ramps, with a correction of 1.15 mm achieved after the first set of aligners.

Blundell *et al.*⁶ reported that only 39.2% of the planned overbite reduction was expressed, using Smart track aligners without bite ramps. In an additional study, Blundell *et al.*⁵ found that when using bite ramps, 43.4% of the prescribed overbite correction was expressed.

A higher percentage was found when using EX30 appliance material without bite ramps, reaching an average of 55.1% in the expression of the prescribed overbite correction.⁵ However, these differences may be explained by previous studies^{5,6} which included patients with an initial overbite of less than 4 mm.

Although a significant difference was found between the simulated and the achieved overbite correction, the present study reported an overall correction of 1.32 mm using appliances made from Smart Track material without bite ramps (specifically, 1.24 mm for the group with a moderate overbite and 1.53 mm for the group with a severely deep bite).

Similar results were also reported in lateral cephalograms by Henick *et al.*²⁴ who found a mean decrease in overbite of 1.3 mm after using precision bite ramps, and by Khosravi *et al.*¹⁹ who reported a mean overbite improvement of 1.5 mm in deep bite patients.

According to previous studies^{5,6} in which a greater overbite correction was associated with a lower prediction accuracy, the present findings showed that larger vertical movements are associated with lower

accuracy (51.35% and 41.56% for moderate and severe deep bite, respectively), although without a significant association between overbite severity and accuracy outcome.

In the current literature, there is a lack of consensus regarding the clinical strategies to treat an anterior deep bite.²⁵ The possible treatment approaches include the extrusion of posterior teeth, the intrusion of maxillary and/or mandibular incisors, the proclination of anterior teeth to obtain relative intrusion, or a combination of these strategies.^{7,26}

However, there is no agreement regarding the accuracy of the opening mechanism in deep bite patients treated using clear aligners. Moreover, defining the precise role of each mechanism in the overall flattening of the curve of Spee may be challenging as they act as reciprocal anchorage units.²⁶

For this reason, the present study calculated not only the accuracy of each individual bite opening mechanism (by comparing their accuracy whether present or absent) but also the accuracy when combining different movements.

In the present findings, lower accuracy in overbite correction was reported when incisor intrusion was planned, in both the upper and lower arches (46.57% and 47.78%, respectively). Similar findings have been reported,^{9,17} with a mean accuracy of intrusion of 45% and 47% for maxillary central incisors. Higher values were reported by Al-Baala *et al.*²⁷ who, using cone-beam computed tomography, reported 51.19% of mean predictability of anterior intrusion and a mean amount of correction of 48.81%, the results of which are consistent with the present outcomes.

By evaluating 3D models, Grunheid *et al.*²⁰ also concluded that aligner treatment was not able to completely achieve the predicted anterior intrusion. In addition to confirming the minimum intrusion of the upper incisors, other studies have reported that the correction of a deep bite using the Invisalign appliance is mainly due to the proclination of the mandibular incisors.¹⁷⁻¹⁹

The present findings confirm the higher mean accuracy of overbite correction when incisor proclination movement has been planned (53.79% for the upper arch and 52.08% for the lower arch).

However, higher values have been reported for posterior tooth extrusion compared to the literature.^{17,18} Although previous studies reported that

extrusion was the most difficult movement to control, with a mean accuracy ranging from 30% to 46%,^{17,18} the present study determined a mean accuracy of 58.25% for lower posterior tooth extrusion.

As a result of the present study, it was decided to determine the correlation between the number of attachments on the lower posterior teeth and the accuracy of overbite correction. Although no significant differences were found (even if the sample size was too small to strengthen the statistical findings), it should be noted that, in most of the included patients, six attachments were planned on the mandibular premolars and molars, which may have improved posterior tooth extrusion. As reported in previous studies,²⁸ the use of attachments may improve vertical tooth movements, even though there is still a lack of evidence regarding extrusive movement.¹

Nonetheless, the improvements in the Invisalign technique, such as the enhanced properties of the Smart Track material or the use of optimised attachments, might be partly responsible for improving the posterior vertical dimension, despite the potential bite-block effect of this appliance.¹⁹

An additional explanation could be the choices of the treatment strategies used by clinicians while planning the tooth movement sequence in the ClinCheck process for the correction of a deep bite. These are likely closely related to the individual skills of the operator.

Limitations

A limitation of the present study was the small sample size. Additionally, the shape, position, and bonding accuracy of attachments were not considered.

Future RCTs with a larger sample size and which evaluate different aligner materials from other companies or in-office settings are needed. Additionally, further studies should investigate the impact of the number of aligners/stages used in treatment and the influence of different attachment shapes and positions, as these factors could potentially influence treatment outcomes differently in cases of severe and moderate deep bite.

Conclusions

The findings of the study may be summarised:

- In adult patients with a severe or moderately deep bite, the overbite correction planned by the ClinCheck program significantly overestimates compared to the clinically achieved overbite correction.
- Larger vertical changes were correlated with larger errors.
- The overall accuracy of the Invisalign system in deep bite treatment is 48.61%, with a higher value for a moderately deep bite (51.35%) compared to a severely deep bite (41.56%) correction.
- The different mechanisms for bite opening (posterior tooth extrusion, anterior tooth intrusion, and incisor proclination) show similar predictability in the achievement of specific planned tooth movements.

Conflict of interest

The authors declare that there is no conflict of interest.

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