Predictability of the deep overbite correction using clear aligners

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Introduction: The objective of this study was to investigate the predictability of overbite correction in patients with deepbite using the clear aligners (Invisalign, Align Technology, San Jose, Calif) and examine the accuracy of vertical movement and inclination change of individual teeth. **Methods:** This retrospective study included 24 deepbite patients (10 males and 14 females; aged 32.8 ± 11.9 years; an initial overbite of 5.20 ± 0.95 mm; an average treatment period of 11.04 ± 4.14 months) consecutively treated from September 2016 and completed before August 2021. SmartTrack materials were used for all patients. The initial, predicted, and achieved final models were exported from ClinCheck and superimposed via best-fit surface-based registration using Slicer CMF (version 4.9.0; cmf.slicer.org). The overbite correction, changes in vertical movement, and inclination for individual teeth were measured. Descriptive statistics and a paired *t* test or Wilcoxon signed-rank test were performed. $P < 0.05$ was considered statistically significant. **Results:** Mean overbite correction was 33%, with a 1.15 mm improvement after the first set of aligners. All teeth demonstrated statistically significant differences between planned and achieved amounts in vertical movement and inclination change, with the largest difference in maxillary central incisors. Mandibular incisor intrusion and mandibular premolar extrusion had similar accuracies. Regarding inclination change, maxillary central incisors showed the lowest accuracy of 13.3%. **Conclusions:** Clear aligner treatment showed an average of 33% overbite correction. Overcorrection and additional refinement treatments are needed in most patients with a deepbite. (Am J Orthod Dentofacial Orthop 2023;163:793-801)

In 1945, Kesling first proposed moving teeth using a preformed tooth positioner.[1,2] However, it involved manual tooth setups in wax models and positioner fabrication for each setup, leading to a lack of popularity. In 1997, Align Technology (San Jose, Calif) launched the Invisalign system with 3-dimensional (3D) computer imaging technologies to facilitate clear aligner treatment (CAT). They made sequential tooth movement setup models using computer software, replacing the previously laborious work. Initially, CAT was used only for minor tooth movements, such as spacing and mild crowding. With the development of new aligner materials (SmartTrack), different attachment designs, efficient tooth movement staging, and an intraoral scanner, clinicians have used clear aligners for more complex cases, including extraction[3] and orthognathic surgery.[4,5] In particular, during the pandemic lockdown, patients could continue their treatment through remote progress checks with their doctors, whereas patients with fixed appliances had to pause their treatment.

Knowing the treatment accuracy of CAT is essential. On the basis of such knowledge, clinicians can predict how much actual tooth movement can be achieved from the 3D planned tooth movement simulations and engineer overcorrection to achieve the appropriate desired movement. The accuracy of CAT was reported in 2009 by Kravitz et al.[6] They demonstrated a 41% mean accuracy of Invisalign treatment focused on maxillary and mandibular anterior teeth, combining the different types of movement including buccolingual and vertical movement, mesiodistal and labiolingual tip, and rotation.[6] They reported that extrusion is the least accurate tooth movement (29.6%). Since 2015, several studies about treatment accuracy using CAT have been published, including systematic reviews, meta-

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
This work was supported by the Schoenleber Pilot Grant from the University of Pennsylvania School of Dental Medicine and the Orthodontic Faculty Development Fellowship Award from the American Association of Orthodontists Foundation.
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Submitted, January 2022; revised and accepted, July 2022.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2022.07.019

analyses, randomized clinical trials, and prospective and retrospective studies.[7-12] These papers have specifically categorized treated patients to examine the precise efficiency of different movements. Rossini et al[7] reported that 0.72 mm of mean intrusion was attempted with aligners, extrusion was the least accurate movement with 30% accuracy, and anterior buccolingual inclination control was ineffective. In addition, Grünheid et al[10] concluded that CAT did not fully achieve anterior intrusion, rotation of rounded teeth, and posterior tooth movements. Khosravi et al[12] reported a 1.5 mm bite opening in deepbite patients and a 1.5 mm bite deepening in open bite patients with Invisalign treatment using cephalometric analyses.[12] The main mechanisms of deepbite correction were via proclination of mandibular incisors, intrusion of maxillary incisors, and extrusion of mandibular posterior teeth. Charalampakis et al[13] examined the accuracy of CAT, including vertical, horizontal, and rotational movements and transverse widths in 20 adult patients with Class I malocclusion. The intrusion of incisors and rotation of canines were the most inaccurate movements, with 1.5 mm of difference between predicted and achieved movements in maxillary central incisors and 3.05° in maxillary canines. Recent review papers[14,15] support that deepbites are difficult to correct using the Invisalign system, with correction ranging from 0.75-1.50 mm intrusion. In 2014, Align Technology developed Invisalign G5 to improve deepbite correction, introducing pressure areas, optimized attachments, and bite ramps. When anterior intrusion and/or 0.5 mm posterior extrusion is planned, the optimized deepbite attachments are included on premolars. When intrusion of mandibular incisors is >1.5 mm, precision bite ramps are added and can be preselected in ClinCheck.[16] A recent study[17] reported a 50% mean accuracy of all tooth movements even after remarkable technological improvements, whereas weaknesses, such as intrusion of mandibular incisors (35%), remained the same. Despite the apparent difficulties in treating deepbites with CAT, the accuracy of studies focused on deepbites is limited.[13,18-22]

This study aimed (1) to determine the accuracy of overbite correction in patients with deepbite using the Invisalign system and (2) to examine the efficiency of individual teeth in vertical movements and inclination changes.

MATERIAL AND METHODS

This retrospective study was approved by the Institutional Review Board at the University of Pennsylvania (protocol no. 834821). All 24 patients with deepbite (10 males and 14 females, aged 32.8 ± 11.9 years) were treated with Invisalign aligners under the supervision of the experienced faculty in the Department of Orthodontics at the University of Pennsylvania School of Dental Medicine. Aligners were changed every 1-2 weeks.[23,24] All subjects received their treatment consecutively between September 2016 and August 2021, when Invisalign had already introduced G5 innovations for deepbites, including precision bite ramps, optimized deepbite attachments, and new pressure areas on lingual surfaces. The sample size was calculated on the basis of an α significance level of 0.05 and 80% power to detect an effect size of 0.6 between measurements. The power analysis showed that at least 24 patients were needed. Inclusion criteria were delineated as follows: (1) Patients with ≥4 mm or ≥50% pretreatment overbite,[12,19,21,25] (2) nongrowing adult patients (aged >18 years), (3) Treatment in both arches with Invisalign, (4) Patients had initial, predicted final, and achieved final scans that could be exported from the Invisalign Doctor Web site, (5) Completion of the initial set of aligners, (6) good compliance with consistent aligner wear, and (7) no restriction on Angle classification. Exclusion criteria were defined as follows: (1) Lack of completion of the first course of aligners, (2) poor compliance with the aligners, and (3) dental restorations before the refinement scan. Seventeen patients had Angle Class I malocclusion, and 7 patients had Class II at least on 1 side on the first molar level. In addition, 2 out of 24 patients had 4 premolars extracted from the previous orthodontic treatment. For those 2 patients, attachments were on premolars and first molars instead of first and second premolars. Patients were asked to wear aligners at least 20-22 h/d per current protocols from the manufacturer. The mean crowding (−) and/or spacing (+) among the subjects was −0.98 mm (−6.0 to 6.0 mm), whereas the mean interproximal reduction (IPR) prescribed was 0.6 mm (0-2.5 mm). IPR was performed as prescribed in each patient's virtual treatment plan.

All initial ClinChecks were approved from September 2016 to September 2020. Two patients were set up with overbite overcorrection, with the final stage of the ClinCheck demonstrating an open bite (−0.4 mm and −0.8 mm). Other patients were set up to establish a normal overbite in the final stage of the ClinCheck. All patients had optimized rotation, optimized deepbite, or conventional horizontal attachments on premolars.

The overbite was measured between 2 antagonistic teeth (lateral or central incisors) comprising the greatest overbite according to the American Board of Orthodontics grading system on the ClinCheck Web site (Fig 1). In addition, we measured overbite in all final models using OrthoCAD (Cadent Inc, Carlstadt, NJ) and the average difference compared with the ClinCheck was 0.20 ±

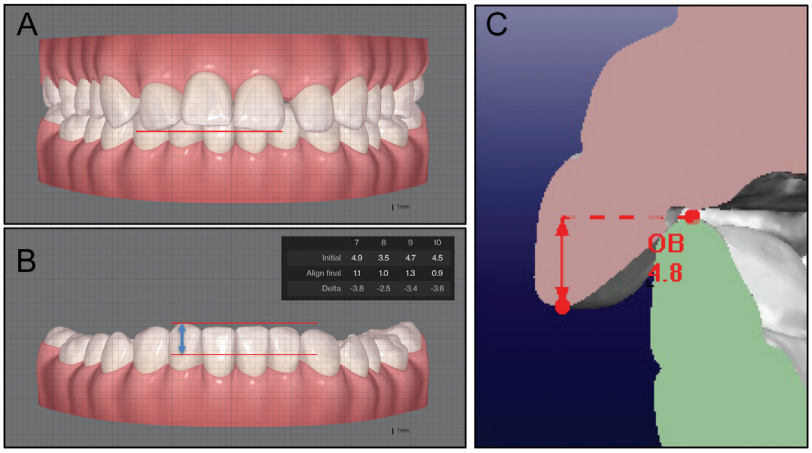

Fig 1. Overbite measurements from ClinCheck: **A,** Maxillary and mandibular models are positioned in the frontal plane. The incisal edge of the maxillary incisor with the largest vertical overlap to the corresponding mandibular anterior tooth is marked; **B,** A maxillary model is removed, and the overbite is measured millimeters from the corresponding grid line; **C,** Overbite was measured using an OrthoCAD.

0.23 mm ($P > 0.05$). A previous study compared measurements from ClinChecks and stone models and reported that ClinCheck measurements provided sufficiently good accuracy.[26] Initial, planned, and achieved overbite were measured (Fig 2).

To analyze individual tooth movements involved in deepbite correction, digital scans were exported from the initial and refinement ClinCheck (Align Technology) as stereolithography files (Fig 3). Initial and predicted final models were taken from the initial ClinCheck, and achieved final models were taken from the first model of the refinement ClinCheck. All models were deidentified and imported into 3D Slicer via the SlicerCMF project (version 4.9.0; cmf.slicer.org). Predicted and achieved models were superimposed over the initial model using best-fit surface-based registration focused on the occlusal surfaces of the first and second molars (Fig 4). The average vertical movement of maxillary and mandibular first and second molars was 0.24 ± 0.21 mm. This software has been used in previous studies comparing treatment outcomes.[13] The amount and direction of planned and achieved vertical movements and inclination changes were measured for individual teeth in the superimposition.

We marked positive when the change occurred in the same direction and negative in the opposite direction. Because one of the main mechanisms for the deepbite correction is the proclination of mandibular incisors, we measured inclination change on maxillary and mandibular central and lateral incisors. For each subject, 40 vertical movements and 16 inclination changes were examined for predicted and achieved movements. Four hundred seventy teeth were measured for vertical change and 190 for inclination change. All measurements were performed on the superimposition between (1) predicted and initial models and (2) achieved and initial models. The vertical change was measured at the cusp tips of canines and premolars and the midpoint of the incisal edges of anterior teeth (Fig 5). Changes in the labiolingual inclination of anterior teeth were calculated by comparing 2 facial axes of the clinical crown lines. The difference in pitch of the 2 lines reflected the labiolingual change of the tooth. Movement for each tooth was measured individually, and contralateral teeth within an arch were grouped. The percent accuracy was calculated as the (achieved amount/predicted amount) × 100%.

Statistical analysis

Statistical analysis was conducted with GraphPad Prism (version 8.4; GraphPad Software, La Jolla, Calif). Descriptive statistics were calculated to describe mean movements, and a paired t test or Wilcoxon signed-rank test was used to assess whether significant changes in overbite and tooth position were achieved. To assess intraexaminer reliability, the same examiner (N.S.) remeasured 10% of the subjects at least 1 month after the initial measurements. The second examiner (J.K.) measured all subjects to evaluate interexaminer reliability. $P < 0.05$ was considered statistically significant.

RESULTS

The mean initial overbite for the study population was 5.20 mm ± 0.95 mm, and the mean initial overjet

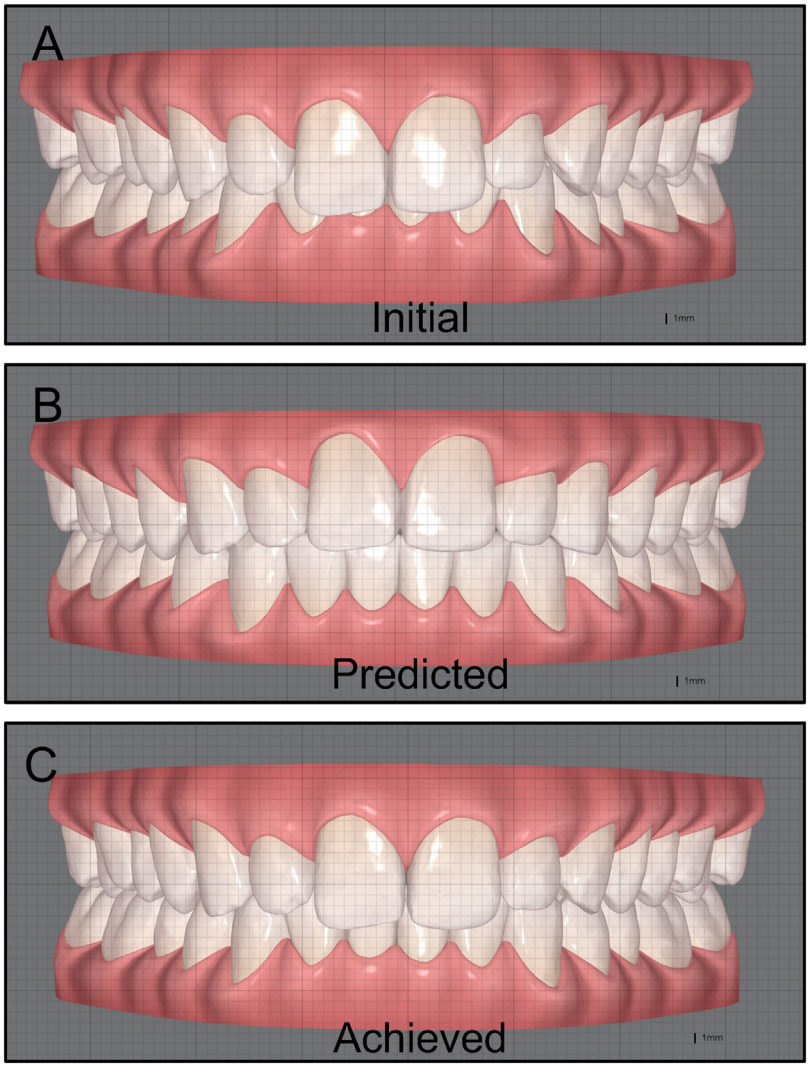

Fig 2. Overbite correction: **A,** Initial; **B,** Predicted; **C,** Achieved overbite correction.

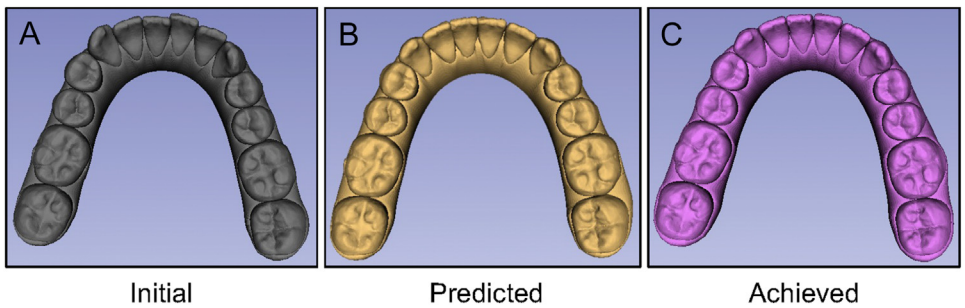

Fig 3. Models exported from ClinCheck: **A,** Initial; **B,** Predicted models were exported from the first ClinCheck; **C,** The achieved model was exported from the initial setup of the first refinement ClinCheck.

was 4.44 ± 1.34 mm (Table I). The average number of aligners was 29.79 ± 11.10. The average time between the initial and refinement scans was 11.04 ± 4.14 months. The overbite correction was achieved with a 33.35% of mean accuracy and a 1.15 mm improvement out of the 3.35 mm planned (Table II).

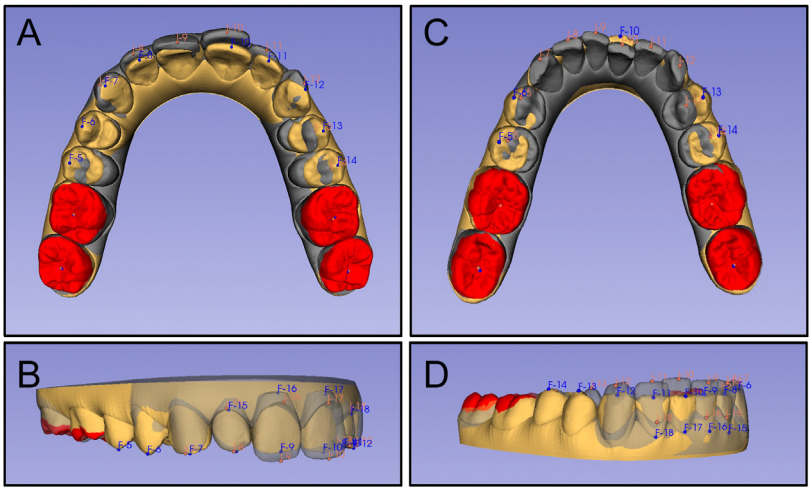

Fig 4. Superimposition and markers. The regions of interest used to superimpose models are highlighted in red on molars. Markers have been placed on cusp tips, centers of incisal edges, and at the intersections of the facial axis and gingival margin of each tooth. **A** and **B**, Maxillary superimposition; **C** and **D**, Mandibular superimposition.

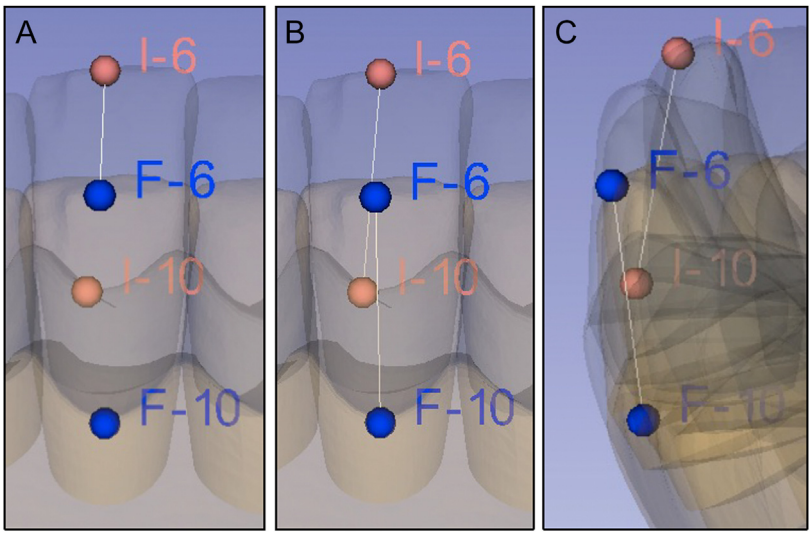

Fig 5. Vertical movement and inclination changes: **A,** The difference in the vertical position of I-6 and F-6 represents the vertical movement of the tooth; **B** and **C,** The difference in angulation from lines I-6 to I-10 and F-6 to F-10 represents the inclination change of the tooth.

There were statistically significant differences between predicted and achieved overbite ($P < 0.05$). In addition, 100% of patients showed >50% initial overbite, of which 66.7% showed >70% overbite. However, only 58.3% had >50% overbite after the initial aligners (Table III).

Although only 6 patients had the bite ramps, 24 had premolar attachments: optimized rotation, optimized deepbite, and conventional rectangular ones. The average overbite correction accuracy for 6 patients with bite ramps was 38.4%, whereas the accuracy for those without bite ramps was 31.7% ($P > 0.05$). In addition, 11 out of 24 patients used intermaxillary elastics, including some patients with Class II canine and Class I molar relationships. However, there was no statistical significance in overbite correction accuracy (%) between the elastics group (41.4%) and the nonelastics group (26.6%) ($P > 0.05$).

Table I. Study population and its characteristics

Characteristics	*n*	*Minimum*	*Maximum*	*Mean ± SD*
Age, y	24	18.34	66.58	32.76 ± 11.88
Initial overbite (mm)	24	4.00	7.00	5.20 ± 0.95
Crowding (−)/spacing (+) per arch (mm)	24	−6.00	6.00	−0.98 ± 3.39
IPR per arch (mm)	24	0	2.50	0.60 ± 0.86
No. of aligners	24	16	65	29.79 ± 11.10
Treatment periods (mo)	24	6	21	11.04 ± 4.14

SD, standard deviation.

Table II. Overbite correction for patients with deepbite

Variable	*n*	*Initial overbite (mm)*	*Predicted (mm) Mean ± SD*	*Achieved (mm) Mean ± SD*	*Significance*	*Mean accuracy (%)*
Overbite correction	24	5.20	3.35 ± 1.17	1.15 ± 1.08	*	33.35

SD, standard deviation.
*Statistically significant ($P < 0.05$).

Table III. Overbite correction for patients with deepbite

Overbite (%)	*Initial overbite*	*Achieved overbite*
<50%	0	10
50%-70%	8	5
70%-100%	14	9
>100%	2	0
Total	24	24

There were significant differences between predicted and achieved movements for all individual tooth movements, including both vertical and faciolingual inclination changes, in both maxillary and mandibular arches (Table IV). In general, mean achieved movements occurred in the planned direction except for the maxillary central and lateral incisors. Although the average 1.14 mm of intrusion was planned, 0.41 mm of extrusion occurred in the maxillary central incisors, with the greatest difference of 1.56 mm ($P < 0.05$). Although 1.04 mm of intrusion was planned, 0.13 mm of extrusion occurred in the maxillary lateral incisors ($P < 0.05$). In contrast, mandibular incisors (combined central and lateral) showed an average of 42.5% accuracy in the same direction. Mandibular premolars (combined first and second) had a mean 46.4% accuracy with the same direction. A labial crown inclination was planned in 87.5% (42/48) of arches. Six arches, which had generalized spacing or very proclined incisors at initial records, presented the palatal/lingual inclination during the treatment. For the inclination change, maxillary central incisors showed the lowest accuracy of 13.3%, followed by maxillary lateral incisors (20.6%), mandibular lateral incisors (37.5%), and mandibular central incisors (50.8%). There was no statistically significant difference in the amount of discrepancy between maxillary and mandibular teeth ($P > 0.05$).

The intraexaminer error between 2 times of measurements was determined using the intraclass correlation coefficient (ICC). The ICC ranged from 0.95 to 0.99, indicating excellent reliability. The interexaminer reliability was good to excellent, with the ICC ranging from 0.76-0.93.

DISCUSSION

Our results for overbite correction demonstrate a large discrepancy between planned (3.35 mm) and achieved movements (1.15 mm) with 33% accuracy after the completion of an initial set of aligners. A recent study in 2021 demonstrated an average 39.2% predictability of overbite reduction using Invisalign, with 95.3% of patients needing refinements to achieve the planned overbite correction.[18] Moreover, they report that the deeper the initial overbite and the more significant programmed overbite reduction in ClinCheck, the greater discrepancy in a posttreatment overbite. In that study, only 50% of patients presented with >4 mm initial overbite, whereas the rest had a smaller overbite. They did not include virtual bite ramps, whereas 100% of our patients had >4 mm overbite, and 6 of our subjects had bite ramps. They showed 30.5% of overbite correction for the population with an initial 4-7 mm overbite, which is consistent with our study. Khosravi et al[12] reported a 1.5 mm bite opening in deepbite patients with Invisalign treatment. This study examined the lateral cephalograms of completed patients and was performed before the

Table IV. Predicted and achieved changes in individual teeth movement of the evaluated samples

Characteristics	*n*	*Predicted (mean ± SD)*	*Achieved (mean ± SD)*	*Significance*	*Difference*
Maxillary arch: vertical (mm)					
U1 vertical	48	1.14 ± 0.75	−0.41 ± 1.03	*	1.56
U2 vertical	48	1.04 ± 0.72	−0.13 ± 0.99	*	1.16
U3 vertical	48	0.77 ± 0.78	0.07 ± 0.88	*	0.70
U4 vertical	48	0.58 ± 0.59	0.08 ± 0.51	*	0.50
U5 vertical	44	0.42 ± 0.37	0.17 ± 0.37	*	0.25
Maxillary arch: inclination (°)					
U1 torque	48	6.88 ± 5.82	0.92 ± 4.70	*	5.96
U2 torque	48	5.89 ± 6.93	1.21 ± 4.34	*	4.68
Mandibular arch: vertical (mm)					
L1 vertical	48	2.48 ± 1.48	1.09 ± 1.28	*	1.39
L2 vertical	46	2.47 ± 1.56	1.02 ± 1.27	*	1.46
L3 vertical	48	1.60 ± 1.18	0.7 ± 1.01	*	0.90
L4 vertical	48	0.56 ± 0.60	0.26 ± 0.50	*	0.30
L5 vertical	44	0.36 ± 0.33	0.17 ± 0.37	*	0.19
Mandibular arch: inclination (°)					
L1 torque	48	6.67 ± 4.98	3.39 ± 4.35	*	3.28
L2 torque	46	7.41 ± 4.89	2.78 ± 5.35	*	4.63

Note. A negative sign indicates that the opposite movement was observed.
SD, standard deviation.
*Statistically significant ($P < 0.05$).

introduction of Invisalign G5 innovation. They reported that mandibular incisor proclination was the main mechanism for opening a deepbite. A recent study in 2021 by Henick et al[20] investigated the effects of virtual bite ramps for skeletal deep overbite patients and compared that with a full fixed appliance treatment. They found both treatments are effective for bite opening with 1.3 mm (Invisalign) and 2 mm (fixed appliance) of mean decrease in an overbite. They also analyzed the lateral cephalograms of pretreatment and posttreatment. Another recent study reported 28.8% and 38.9% of overbite correction in patients with Class I and Class II malocclusion, respectively, though they did not provide the vertical information of patients.[27] The differences among studies can partly be explained by different analysis methods (lateral cephalograms vs superimposition of 3D models) and different treatments (initial set of aligners vs completed patients).

We found that all vertical and faciolingual movements of individual teeth showed a significant difference between planned and achieved movements, and maxillary central incisors demonstrated the largest discrepancy, consistent with previous studies.[10,13] We planned a mean 1.14 mm intrusion on maxillary central incisors but found 0.41 mm extrusion from the superimposition of achieved and initial models. Charalampakis et al[13] also reported the opposite movement of maxillary central incisors with 1.5 mm of median difference compared with the planned direction. A recent cone-beam computed tomography study to assess the anterior intrusion with Invisalign revealed 51.19% of mean predictability and 48.81% of correction after an initial series of aligners.[19] They found that both maxillary and mandibular anterior intrusion were inaccurate, with a significant difference between the predicted and actual movement, which is consistent with our study. Henick et al[20] reported that the maxillary incisors were intruded 0.88 mm in the Invisalign group with virtual bite ramps using lateral cephalometric x-rays of posttreatment. Grünheid et al. found that the maxillary central incisor was significantly more occlusal than predicted, with −0.3 mm of difference, using a best-fit surface-based registration for superimposition.[10] Different outcomes might come from the different analysis methods, such as radiographic x-rays vs 3D model superimposition.

We found about 1 mm of intrusion of mandibular incisors with 42.5% accuracy. Krieger et al[26] reported 14.3% of anterior intrusion accuracy, which was the most difficult to achieve. Both Grünheid et al[10] and Charalampakis et al[13] found mandibular incisor intrusion to be an inaccurate movement. Henick et al[20] reported a 1.30 mm intrusion of mandibular incisors with virtual bite ramps. Kravitz et al[22] reported that incisor intrusion remains a difficult movement with a 35% accuracy, even with the latest enhancements from Invisalign. Given that the SmartForce protocol places anchorage as a low priority, the inadequate anchorage setup may be a reason for the low accuracy.

Maxillary central incisors showed the largest mean difference of 5.96° in torque among maxillary and

mandibular incisors, possibly because of their larger tooth size. Tepedino et al. reported that predicted torque movements were generally achieved with 12 aligners, using a different aligner system and analysis methods.[28] However, the average planned torque movement in their study was only 2.6°, much less than in our study (6.88°). Lombardo et al[9] reported the mean difference was 4.5 ± 4° for torque movement of maxillary central incisors. Simon et al[29] reported a loss of torque in maxillary central incisors up to 50% in their study regardless of the presence of an attachment or a power ridge, though they had a different patient population and analysis method for superimposition and torque measurement. Regarding mandibular incisor inclination changes, we achieved 3.39° and 2.78° of change for mandibular central and lateral incisors, respectively, whereas the planned changes were 6.67° and 7.41°. Hennessy et al[30] found a 3.4° mandibular incisor proclination in patients with mild crowding. Lombardo et al[9] reported that the mean imprecision of mandibular incisor movements was approximately 2.9°, whereas the mean prescription was 5.9°.

In our study, the average overbite correction accuracy for 6 patients with bite ramps was 38.4%, whereas for those without bite ramps were 31.7% ($P > 0.05$). Bite ramps are included when the mandibular incisor intrusion is >1.5 mm. In addition, 11 out of 24 patients used intermaxillary elastics, including some patients with Class II canine and Class I molar relationships. However, there was no statistical significance in overbite correction accuracy (%) between the elastics group (41.4%) and the nonelastics group (26.6%) ($P > 0.05$). A bigger sample size is needed to assess the effect of bite ramps and elastics on overbite correction.

To overcome the low accuracy of deepbite correction with the Invisalign system, overtreatment is generally recommended in the final occlusion on the ClinCheck software, including an anterior edge-to-edge or slight open bite, a reverse curve of Spee in the mandibular arch, and heavy posterior occlusal contacts.[31] Voudouris et al[21] recommended 150%-200% overbite supercorrection depending on the initial severity of overbite, including IPR to reduce contact compression, using a bite ramp, and using chewies between maxillary and mandibular anterior teeth.[21] In our study, 100% of patients had attachments on premolars, including optimized deepbite or rotation attachments. Optimized rotation attachments have higher priority if a premolar is rotated >5° than overoptimized deepbite attachments. To prepare solid anchorage for anterior teeth intrusion, clinicians can ask for a replacement with optimized deepbite attachments or horizontal rectangular attachments. Most recently, Invisalign introduced the G8 system to improve clinical predictability in deepbite correction, using individual activation on anterior teeth to optimize the intrusion force level.[16] Considering the difficulty of deepbite correction using the Invisalign system because of material characteristics, a combination of maxillary Invisalign aligners and mandibular fixed appliances could be an alternative option to meet both esthetic and functional demands.[17]

There were several limitations in our study. Firstly, the main limitation was a lack of stable structures for ClinCheck superimpositions. Generally, the palatal rugae are considered stable and used for the superimposition of maxillary arches. As ClinCheck only provides the clinical crowns and gingiva, superimposition on the stable teeth, the occlusal plane, and best-fit algorithms have been used in previous studies.[10,13,24] Because of the limitation, the individual tooth movement analysis in our study might be affected by the molar movement. The average movement of maxillary and mandibular first and second molars was 0.24 ± 0.21 mm. Secondly, we focused on dental deepbites, not the skeletal condition. Generally, skeletal deepbite correction is more difficult than dental deepbite correction.[32,33] Furthermore, 6 patients in our study had bite ramps, but the use of bite ramps ideally depends on the patient's skeletal vertical type. For example, in skeletal deepbite patients, we extrude the mandibular posterior teeth while intruding anterior teeth with bite ramps. However, we should avoid posterior extrusion in hyperdivergent patients. Thirdly, we examined only the first course of aligners in our study. Considering that most patients need additional refinements to achieve the final planned occlusion, it would be interesting to examine if there is any difference in treatment accuracy between initial and refinement treatments. Finally, we need a bigger sample size to precisely assess the effect of bite ramps and elastics on overbite correction.

CONCLUSIONS

In this study, we found an average of 33% accuracy of overbite correction in a deepbite population using Invisalign. All vertical movements and inclination changes showed a statistically significant difference between planned and achieved movements after the initial aligner wear. Overcorrection and additional refinements are needed in almost every patient.

AUTHOR CREDIT STATEMENT

Nishat Shahabuddin contributed to the methodology, data curation, formal analysis, and original draft preparation; Jessica Kang contributed to the formal analysis and manuscript review and editing; Hyeran

Helen Jeon contributed to the conceptualization, methodology, validation, supervision, manuscript review and editing, resources, and funding acquisition.

ACKNOWLEDGMENTS

We greatly appreciate Dr John Voudouris for his helpful discussion.

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ajodo.2022.07.019.

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