Letter to the editor

Invisalign treatment achieved and predicted results

We appreciate Dai et al. for an interesting article on treatment using Invisalign, published in December 2021 (Fan-fan D, Tian-min X, Guang S. Comparison of achieved and predicted crown movement in adults after 4 first premolar extraction treatment with Invisalign. Am J Orthod Dentofacial Orthop 2021;160:805-13).

However, we have a few comments and wish to seek further explanation on the following:

1. Out of 17 patients, 4 had cusp-to-cusp Class II molar relationship requiring planned mesial movement of mandibular molars, and 1 had cusp-to-cusp Class III relationship, requiring planned mesial movement of the maxillary molar. Was there any planned mesial movement of the molars in the patients with Class I malocclusion? An independent data analysis on patients with Class I malocclusion could have provided insight into the amount of unwanted mesial molar movement during Invisalign treatment.
2. The maxillary molars were predicted to tip distally and lingually, whereas mandibular molars were predicted to tip distally and buccally. Were these predictions based on the original ClinCheck plan? If modifications were done, what was the rationale? Was the same amount of distal tip added to patients with Class I, Class II, and Class III malocclusions?
3. Among the 4 patients with Class II malocclusion, 1 used bilateral Class II elastics, and 2 used unilateral Class II elastics. What was the plan to correct Class II malocclusion in the fourth patient? What were the mechanics of correction of Class III malocclusion?
4. Why were the maxillary molars predicted to extrude and mandibular molars predicted to intrude? Similarly, why were the maxillary incisors predicted to extrude and mandibular incisors predicted to intrude when the initial overbite was only 2.1 ± 1.1 mm? If the purpose was to maintain the overbite or prevent bite deepening during the retraction, a ClinCheck plan that extrudes both maxillary and mandibular molars and intrudes incisors in both arches could have served better.
5. What is interincisor width, and how was it measured?
6. What were the mean overjet and the amount of space remaining in each arch at the end of the initial set of aligners?
7. Has it been scientifically proven that rapid space closure would lead to a buccal inclination of the maxillary molars and lingual inclination of the mandibular molars?[1] Buccal inclination, observed previously during aligner treatment,[2] could be primarily because of the nonextraction method of treatment, in which clinicians tend to gain space by arch expansion and secondarily by the failure of aligners to obtain adequate buccal root torque.

We would appreciate it if you could provide these details.

In addition, it is worth mentioning that the data is widely distributed, as shown by the large standard deviation, and hence less reliable.

Sarah Anvery
Pramod Philip
Buffalo, NY

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Authors' response

We thank the authors of the letter for giving us the opportunity to further explain the results of our study.

We agree that a sample with only patients with Class I malocclusion would provide more accurate evidence of molar movement during Invisalign treatment. For the 12 patients with Class I malocclusion, the maxillary molar was predicted to move mesially by 0.95 ± 1.11 mm, but actually moved by 2.53 ± 0.81 mm, with a difference of 1.58 ± 1.06 mm, and the mandibular molar was predicted to move mesially by 1.11 ± 1.00 mm, but actually moved by 1.55 ± 0.85 mm, with a difference of 0.44 ± 1.11 mm. Not only Angle's Classification but sagittal and vertical skeletal Classification may

influence the difference between predicted and achieved tooth movement. However, as the sample that met the inclusion criteria was limited, we did not do further grouping.

The letter pays attention to the rationale of our ClinCheck plans. Modifications were generally done to the original ClinCheck plan; we added additional amounts of the distal tip to the maxillary and mandibular molars just as anchorage preparation in the tweed technique, expecting better anchorage control effect. The mean distal tip added to patients with Class I, Class II, and Class III malocclusions was 3.36°, 3.01°, and 0.26°, respectively, in the maxillary first molar and 1.89°, 4.95°, 2.33°, respectively, in the mandibular first molar. The greater amount of distal tip added to the maxillary molar in patients with Class I and Class II malocclusions were to resist mesial translation during space closure and greater amount of distal tip added to the mandibular first molar in patients with Class II malocclusion was to resist mesial tipping with Class II elastics (Fig 1). An additional small amount of lingual tip to the maxillary molar and buccal tip to the mandibular molar was added to prevent buccal inclination of the maxillary molar and lingual inclination of the mandibular molar using the experience of fixed orthodontics.

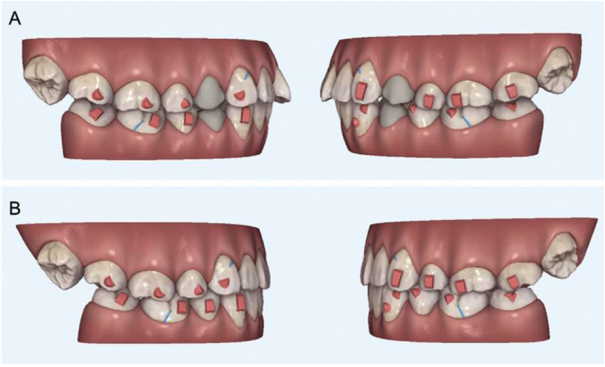

Fig 1. The patient with Class II malocclusion planned with a great amount of distal tip in molars to reinforce maxillary molar anchorage and resist mesial tipping of mandibular molar with Class II elastics. **A,** Pretreatment dental models; **B,** Predicted posttreatment dental models.

Figure 2 shows the ClinCheck plan, treatment result, and registration result of the patient with Class II malocclusion without Class II elastics. The Class II molar relationship on the right side was corrected through sequential mesialization of the mandibular posterior teeth using v-pattern staging, whereas the mandibular posterior teeth on the other side were fixed as an anchorage, and no mesialization of posterior teeth were designed in the maxillary arch (Figs 2, *A*, *B*, and *E*). The molar relationship was almost achieved as predicted (Fig 2, *C*), but the registration result (Fig 2, *D*) tells the real truth. The maxillary right first molar was predicted no mesial movement but actually moved by 1.5 mm, whereas the mandibular right first molar was predicted to move mesially by 1.3 mm but actually moved more by 0.7

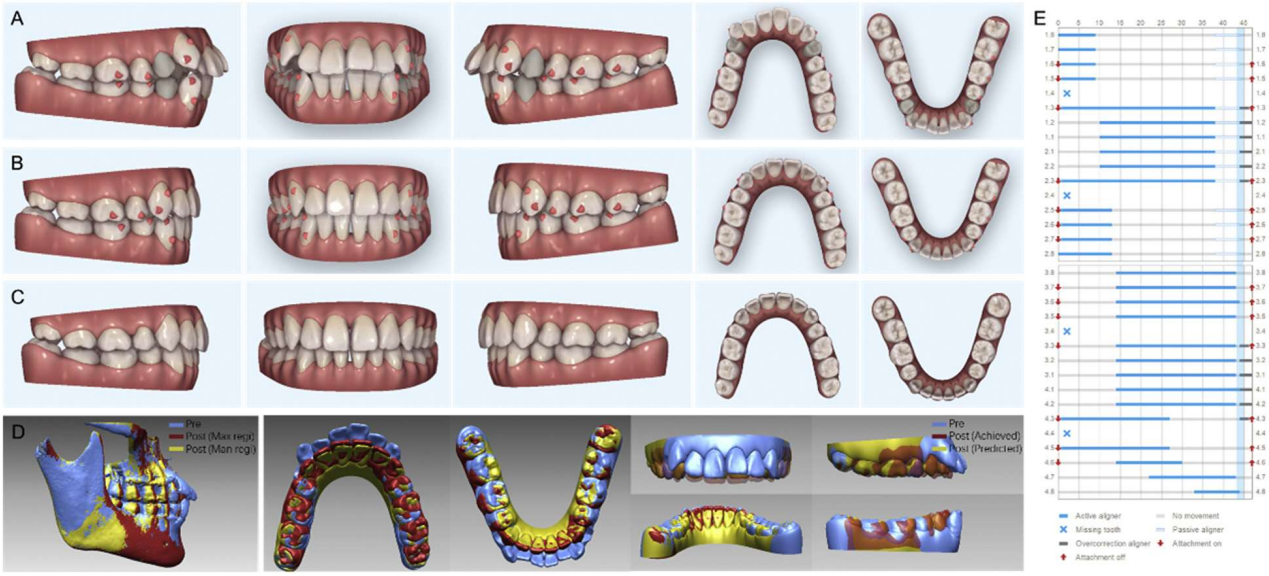

Fig 2. ClinCheck plan, treatment result, and registration result of a patient with Class II malocclusion without Class II elastics. **A-C,** Pretreatment, predicted posttreatment and actual posttreatment dental models; **D,** Registration of craniofacial models and registration of dental models; **E,** Staging chart.

Fig 3. ClinCheck plan, treatment result, and registration result of a patient with Class III malocclusion without Class III elastics. **A-C,** Pretreatment, predicted posttreatment and actual posttreatment dental models; **D,** Registration of craniofacial models and registration of dental models.

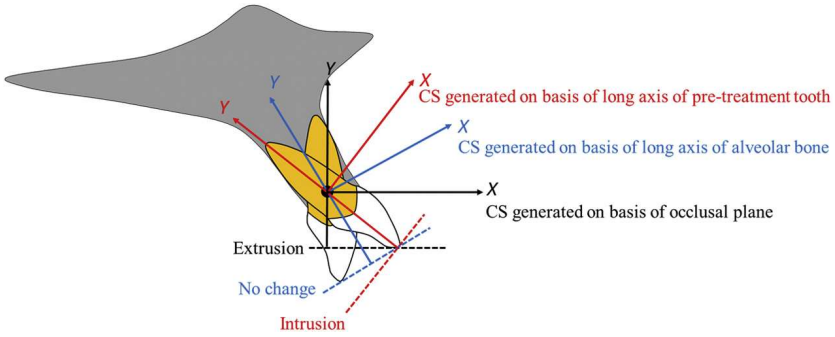

Fig 4. Coordinate systems generated on the basis of the tooth (*red*), occlusal plane (*black*), and alveolar bone (*blue*) outputs different vertical tooth movement results.

mm; thus, the net difference in mesialization between maxillary and mandibular right first molars was only 0.5 mm, not 1.3 mm as designed. In contrast, the difference between the posttreatment craniofacial model after maxillary registration and after mandibular registration indicated slight mandibular advancement posttreatment, which also contributed to the correction of the Class II molar relationship. However, inadequate intrusion and torque control of incisors were obvious in this subject.

Figure 3 shows the ClinCheck plan, treatment result, and registration result of the patients with Class III malocclusion without Class III elastics. The Class III molar relationship on the right side was corrected through mesialization of the maxillary first molar by 1.1 mm and stabilization of the mandibular first molar in the ClinCheck plan (Figs 3, *A* and *B*). Class III elastic was not used as the experience from fixed orthodontics told us that maxillary molar anchorage was weaker than mandibular molar anchorage. The treatment result showed improvement in the molar relationship (Fig 3, *C*). The registration result showed that the maxillary and mandibular first molars moved mesially by 2.5 mm and 1.3 mm, respectively; thus, the net difference was similar to that of the plan (Fig. 3, D). However, the mesial

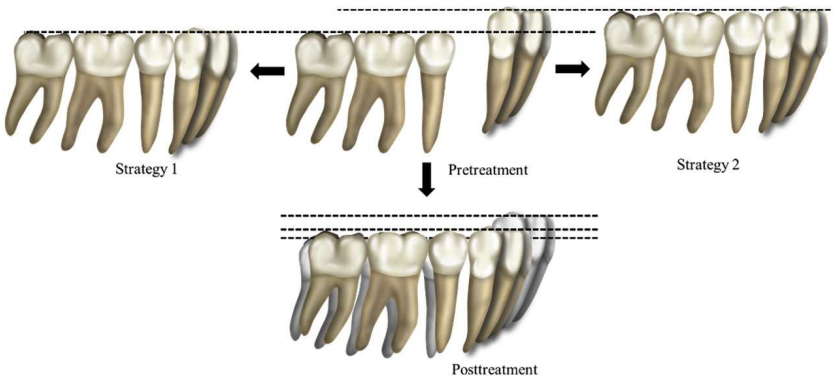

Fig 5. Different strategies in Spee's curve leveling may have similar treatment results.

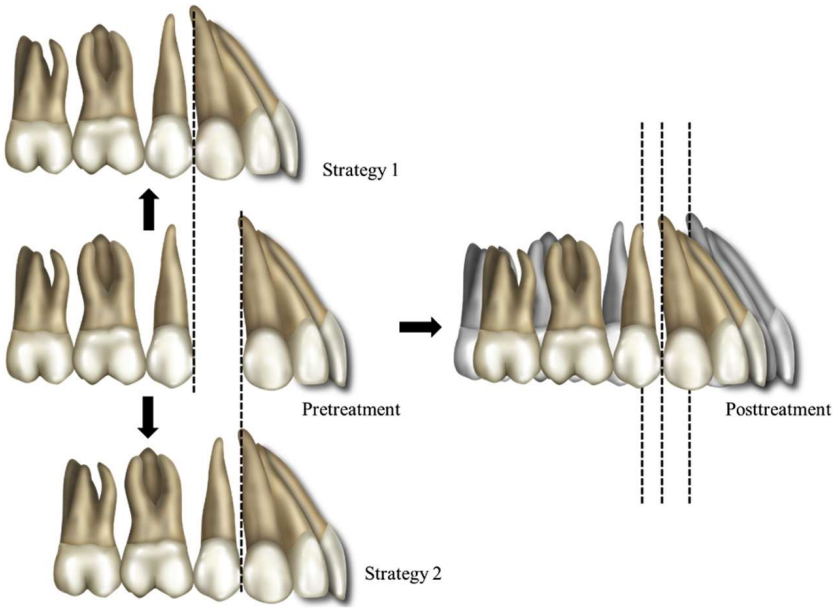

Fig 6. Different strategies in extraction space closure may have similar treatment results.

and buccal tip of maxillary and mandibular molars, intrusion of maxillary molars, and open bite in the posterior segment were obvious in this subject.

In clinics, we modify the ClinCheck plan with the Tooth Movements Table (TMT) as a reference. Both the maxillary and mandibular incisors were planned to intrude when calculating the values in the TMT, and the intrusion amount was 2.6 ± 1.6 mm and 3.2 ± 1.4 mm, respectively. As the letter said, we expected to prevent bite deepening through the intrusion of both maxillary and mandibular incisors. However, this calculated result is quite different from the result in this study, in which the maxillary incisors were predicted to extrude by 0.8 ± 1.0 mm, and the mandibular incisors were predicted to intrude by 1.7 ± 1.3 mm. Why? The main reason was that different reference coordinate systems were used. Figure 4 illustrates the difference between these 2 coordinate systems. In the ClinCheck software, an individualized coordinate system is generated on the basis of the long axis of each pretreatment tooth. When a proclined incisor is planned to tip lingually, the TMT usually outputs a significant intrusion, which is very misleading. When using a coordinate system generated on the basis of the occlusal plane as in the present study, the calculated result is an extrusion, and this is close to the relative extrusion and/or intrusion in the ClinCheck Web, which was not released until last year. However, in our opinion, both coordinate systems have disadvantages; a coordinate system generated on the basis of alveolar bone would

be more reasonable as the nature of tooth movement is alveolar bone remodeling, and evaluation of tooth movement relative to alveolar bone is more meaningful in clinics.

In addition, the reference point of the tooth crown is the geometric center in ClinCheck TMT, whereas the cusp or midpoint of the incisor edge in this study also contributes to the difference in tooth movement values.

As to predicted vertical movement of molars, it came from the original ClinCheck plan; we did not do modifications to this variable. Moreover, the difference between a strategy of extrusion by 3 mm in posterior teeth and no movement in anterior teeth and a strategy of no movement in posterior teeth and intrusion by 3 mm in anterior teeth may be just a trick, unless special biomechanical approaches like sequential intrusion or extrusion are designed (Fig 5). The trick could also be seen in extraction space closure strategies unless special anchorage control approaches are used (Fig 6). The actual tooth movement would be influenced by biomechanics rather than where we put the tooth blocks.

We thank the letter pointing out the variable interincisor width, it was measured as the distance between 2 midpoints of the incisor edge of the central incisor in the z-axis. As arch width is usually measured on canines and posterior teeth and interincisor width is of no clinical significance, interincisor distance instead of interincisor width would be more proper to indicate incisors' movement in the mesiodistal direction.

The mean overjet was 2.5 ± 0.9 mm, and the amount of space remaining in the maxillary and the mandibular arch was 0.9 ± 0.9 mm and 0.4 ± 0.4 mm, respectively.

We appreciate your rigorous attitude toward this study. Unfortunately, after searching the database, we find studies about the buccolingual changes of molars only in untreated subjects and nonextraction patients, but not in extraction patients. However, the buccal inclination of molars was evident in the extraction clear aligner treatment (Fig 3) though the intermolar width was not increased. The buccal inclination of molars might result from outward and upward flexing of the aligners in the maxillary first molar segment and outward and downward flexing of the aligners in the mandibular first molar segment because of rapid shortening of the aligners along with rapid extraction space closure.

Overall, questions raised in the letter concentrated on our ClinCheck plans. We had not developed a mature strategy in extraction patients when the G6 strategy was also just released by the company. Our strategy was based on clinical results of previous clear aligner patients and experience in fixed orthodontics. Thus, we tried a lot in the ClinCheck plans, for example, different amounts of molar anchorage preparation, overcorrection vs no overcorrection, elastics vs no elastics, G6 strategy vs non-G6 strategy, etc, and these contributed to the large standard deviation in the predicted and achieved values in addition to the individualized variability because of the small sample. However, the present study focused on the difference between predicted and achieved tooth movement, and a paired t test was used in this self-control study. The standard deviations of difference between predicted and achieved tooth movement were not quite large. Some negative results might be false negatives, but the positive results were more reliable.

Fan-Fan Dai
Guang Shu
Beijing, China

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Maxillary molar distalization using Invisalign

We congratulate Saif et al for their publication (Saif BS, Pan F, Mou Q, Han M, Bu W, Zhao J, et al. Efficiency evaluation of maxillary molar distalization using Invisalign based on palatal rugae registration. Am J Orthod Dentofacial Orthop 2022;161:e372-379). This was an interesting study, and we would like to put forward a few queries.

1. The authors have not quantified the amount of distalization (half cusp or full cusp Class II) required in the inclusion criteria.
2. The authors have mentioned in the inclusion criteria that "adequate space should be present for distalization of first and second molars." What quantitative measurement was performed by the authors to determine the adequate space available for distalization?
3. What was the power of the study? How did the authors calculate the sample size as no reference article has been quoted?
4. The sample size mentioned in the article is 38 subjects, out of which first, second maxillary molars and anterior teeth were taken for all patients, which adds up to 152 molars and 228 anterior teeth. However, in the article, the authors have mentioned that 142 molars were investigated. Why have they not mentioned the remaining 10 molars?
5. The authors have used the entire palatal rugae area following the contour of the gingival margins of the