Class II malocclusion correction with Invisalign: Is it possible?

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Introduction: This research aimed to determine whether Class II malocclusion can be treated with clear aligners after completing treatment with the initial set of aligners. **Methods:** A sample of 80 adult patients were divided into Group 1 with Class I molar malocclusions ($n = 40$ [11 men and 29 women]; 38.70 ± 15.90 years) and Group 2 with Class II molar malocclusions ($n = 40$ [11 men and 29 women]; 35.25 ± 15.21 years). All patients had finished treatment with the initial set of Invisalign aligners (Align Technology, Santa Jose, Calif) without known centric occlusion–centric relation discrepancies, issues of compliance, or overcorrection. The 7 measurements using the American Board of Orthodontics (ABO) Model Grading System and millimetric measurements for anteroposterior (AP) and vertical dimensions were assessed and compared between the 2 groups at pretreatment, posttreatment ClinCheck (Align Technology) prediction, and posttreatment. **Results:** No improvements were observed in the AP correction. The amount of AP correction in patients with Class II malocclusion was 6.8% of the predicted amount. The amount of overbite correction achieved was 28.8% and 38.9% of the predicted amounts in patients with Class I and Class II malocclusion, respectively. Significant improvements in alignment and interproximal contact scores were observed, with only slight improvements in total ABO scores. An increase in mean occlusal contacts score was observed after treatment. No patient with Class II malocclusions would meet the ABO standards after Invisalign treatment. **Conclusions:** The Invisalign system successfully achieves certain tooth movements but fails to achieve other movements predictably. No significant Class II correction or overjet reduction was observed with elastics for an average of 7-month duration in the adult population. Additional refinements may be necessary to address problems created during treatment, as evidenced by a posterior open bite incidence. (Am J Orthod Dentofacial Orthop 2021;159:e41-e48)

As early as 1945, orthodontists used aligners to correct minor tooth movements; however, comprehensive orthodontic treatment was deemed impractical because of the number of impressions and laboratory time required to fabricate each aligner.[1] Invisalign (Align Technology, San Jose, Calif) clear aligners originated in 1997, when Stanford student Zia Chishti, an orthodontic patient turned entrepreneur, received a clear retainer from his orthodontist for retention. Using the design software in a computer laboratory at the university, Chishti and his partners learned how to simulate a solid object with a computer-aided design model and then recreate that object using 3-dimensional printing technology. Through this technology and sequential staging of tooth movements capable of generating orthodontic forces, the Invisalign system was developed under the company name Align Technology.[2,3] Currently, more than 7.5 million Invisalign cases have shipped worldwide with yearly net revenues exceeding $2.3 billion.[4] Most recently, Align has released the first U.S. Food and Drug Administration–approved clear aligner treatment for Class II malocclusion, termed Invisalign with mandibular advancement.

With the improvements in aligner materials, attachment design, and 3-dimensional software,[5] the scientific community has responded with research measuring the success or failure of these technological progressions by measuring achieved individual tooth movements and comparing them with their predicted models. Some of the most notable conclusions in comparison with fixed appliances include the following: aligner cases demonstrated significantly poorer root control during extraction space closure,[6-9] shorter treatment duration by 5.7 months on average, and higher Peer Assessment

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Rating scores.[10] Studies comparing achieved vs predicted tooth movements demonstrated a total tooth movement accuracy of 41%, with extrusion, mandibular canine rotation, and labial crown movement measured at 29.6%, 29.1%, and 37.6%, respectively.[11] Average vertical changes observed were between 0.9 mm and 1.5 mm,[12,13] whereas anteroposterior (AP) movement via maxillary molar distalization was highly predictable (88% accuracy) when at least 1.5 mm of translation was prescribed.[14]

Some recent studies have evaluated posttreatment results using the American Board of Orthodontics (ABO) Model Grading System (MGS). Findings indicated that Invisalign-treated patients lost 13 MGS points more than patients treated with conventional braces. These scores were consistently lower for buccolingual inclination and overjet criteria, with occlusal contacts and occlusal relationship scores worsening with treatment.[15,16] Extraction cases with Invisalign have demonstrated increased treatment times compared with braces and poorer MGS scores.[17] Retention studies have shown significantly more relapse among patients treated with Invisalign.[18]

The present study serves to expand our knowledge of aligner treatment for patients with Class II malocclusions. Previous research has objectively evaluated posttreatment models, but with an unspecified number of refinements over an unspecified amount of time; this method skews the predicted and achieved accuracy for tooth movements. After completing treatment with the initial set of aligners, the evaluation of patients can thoroughly compare the initial, predicted, and achieved results over a specific period. Thus, the purpose of the study was to determine whether Class II malocclusion can be treated with Invisalign after completion of the treatment with the initial set of clear aligners.

MATERIAL AND METHODS

A total of 80 Invisalign-treated patients were selected for inclusion in this retrospective study, enough for a sampling error of 10% of the mean with a critical confidence value ($Z_{\alpha/2}$) equal to 1.645 ($\alpha = 0.10$) and 90% confidence level. The sample was divided into group 1 with Class I malocclusions ($n = 40$ [11 men and 29 women]; age, 38.70 ± 15.90 years) and group 2 with Class II malocclusions ($n = 40$ [11 men and 29 women]; age, 35.25 ± 15.21 years). Classifications were determined from molar relationships, as defined by the ABO, and canine relationships.

For Class II malocclusions, both end-on and full-step molars were included in the study; unilateral Class II relationships were also included. Both age and gender—29 women and 11 men per group—were matched before analysis of records to ensure even distribution. Treatments were completed by an orthodontic specialist with extensive experience in treating with clear aligners.

A Patient Data Checklist was created with the following inclusion criteria: no known reported issues of compliance, no known centric occlusion–centric relation discrepancy, no overcorrection planned, no interproximal reduction performed immediately before refinement scan, completion of all active aligners in ClinCheck (Align Technology), patients whose treatment finished after 2014 with SmartTrack (Align Technology) material, and adult patients aged 18 years and older. Overcorrection was defined as values outside of the normal range for that particular dental measurement, as defined by the ABO Discrepancy Index. For example, the range for normal overbite is >1 to ≤ 3 mm, yielding 0 points to the overall score. There were no limitations on missing teeth (except canines) or history of orthodontic treatment. Patients with dental bridges and those having planned extractions were not included in the study.

The protocol for evaluating digital model files at pretreatment (T1), posttreatment ClinCheck prediction (T2A), and posttreatment (T2B) were obtained from the Invisalign Web site. For this research, posttreatment was defined as the end of the first set of active aligners. Next, ClinCheck Pro (version 5.4; Align Technology) software was used to view the files and perform the digital measurements.

The measurements of the ABO MGS, including alignment, marginal ridges, buccolingual inclinations, occlusal contacts, occlusal relationships, overjet, and interproximal contacts, were assessed at T1, T2A, and T2B (Table I).[19] Root parallelism was omitted from the analysis, similar to a previous study.[20] Both overbite and AP relationships were also recorded in millimeters on the Patient Data Checklist. The amount needed was calculated using an ideal overbite and AP relationship. Measurements for each component were made from the digital models according to the protocol established in the ABO Grading System for Dental Casts and Panoramic Radiographs.[19] All measurements were made by investigator (B.D.P.) who had successfully completed the ABO Calibration Kit administered by a current ABO Director. All scores were recorded on the Cast-Radiograph Worksheet. The ClinCheck Pro software allowed the use of a digital ruler instead of a standard ruler (Fig 1). Because no measurement required precision finer than 0.5 mm, the proposed method for digital measurements provided the optimal accuracy required. According to ABO guidelines, a case that scores more than 30 points would likely fail, less than 20 points would likely

Table I. ABO measurements and intrarater reliability

ABO measurement	*Description*	*Cronbach α*
Alignment	In the anterior region, the incisal edges with the lingual surfaces of the maxillary teeth and the labial surfaces of the mandibular teeth. In the posterior region, the mesiodistal central groove of the maxillary teeth and the buccal cusps of the mandibular teeth.	0.903
Marginal ridges	These are used to assess the proper vertical positioning of the posterior teeth, which should be at the same level.	0.945
Buccolingual inclination	This is used to assess the angulation of the posterior teeth to establish maximum intercuspation and avoid balancing interferences.	0.938
Occlusal contacts	These are used to measure the adequacy of the posterior occlusion and maximum intercuspation of the opposing teeth.	0.973
Occlusal relationship	This is used to assess the AP position of the maxillary and mandibular posterior teeth.	0.984
Overjet	This is used to assess the AP relationship of anterior teeth and transverse relationship of posterior teeth.	0.831
Interproximal contacts	This is used to assess spacing within the dental arch.	0.923

pass, and between 20 and 30 points would be considered borderline.

The percentage of treatment accuracy for the ABO MGS measurements was calculated by 2 methods, depending on which model was used as the gold standard. If the predicted ClinCheck is the standard, then the formula is defined as percentage accuracy = (initial − achieved)/(initial − predicted) × 100. The percentage of treatment accuracy for AP movement and overbite achieved was calculated by the following equation: percentage accuracy = amount achieved/amount predicted × 100.

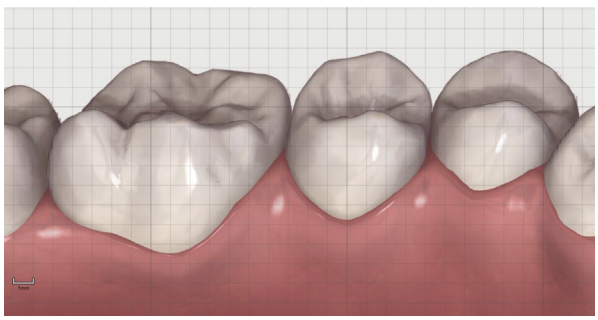

Fig 1. ClinCheck millimetric grid.

Table II. Class I descriptive and paired *t* test statistics

	Descriptive						*Paired* t *test*	
	T1		*T2A*		*T2B*		*T1-T2B*	*T2A-T2B*
Variables	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Sig*	*Sig*
Total score	35.25	8.84	12.00	5.35	27.53	8.42	0.000*	0.000*
AR	20.85	6.27	2.75	1.63	7.30	3.74	0.000*	0.000*
MR	3.10	2.10	2.10	1.50	3.10	2.24	1.000	0.001*
BI	2.30	1.62	1.95	1.62	2.40	1.77	0.440	0.002*
OJ	3.35	2.68	2.40	2.69	3.13	2.78	0.540	0.032*
OC	2.90	2.64	2.68	2.46	10.60	4.11	0.000*	0.000*
OR	0.65	1.05	0.13	0.34	0.73	1.01	0.645	0.000*
IC	2.13	4.92	0.15	0.95	0.30	0.91	0.015*	0.486

SD, standard deviation; *Sig,* significance; *AR,* alignment; *MR,* marginal ridges; *BI,* buccolingual inclination; *OJ,* overjet; *OC,* occlusal contacts; *OR,* occlusal relationship; *IC,* interproximal contacts.
*Paired *t* test was significant at the 0.05 level (2-tailed).

Statistical analysis

Descriptive statistics were calculated for all variables. Because the data distribution was not normal, the nonparametric equivalents were used for statistical analysis. Wilcoxon signed rank (paired *t*) tests were used to identify intragroup differences. Mann-Whitney U (independent *t*) tests were used to evaluate intergroup differences. Intraexaminer reliability was evaluated after remeasuring 10% of the sample and reported with Cronbach alpha; $\alpha = 0.05$ was used as the level of statistical significance for all analyses.

RESULTS

Descriptive statistics for the ABO MGS measurements at T1, T2A, and T2B, and the comparisons between the time points were shown in Tables II and III for patients with Class I and Class II malocclusion, respectively. Intrarater reliability ranged from 0.831 to 0.984 (Table I). Assuming a passing threshold of 27 or lower, all of the predicted ClinCheck occlusions (T2A) would meet ABO standards, but only 47.5% and 0% of posttreatment occlusions (T2B) would pass in the Class I and Class II malocclusion groups, respectively. After treatment, improvements were noted in the total ABO scores, alignment, and interproximal contacts, but significant differences remained compared with the predicted scores. No improvements were observed in marginal ridges, overjet, or occlusal relationships at posttreatment. Occlusal contacts were the only category that scored worse with treatment. The average number of

Table III. Class II descriptive and paired *t* test statistics

	Descriptive						Paired t test	
	T1		T2A		T2B		T1-T2B	T2A-T2B
	Mean	SD	Mean	SD	Mean	SD	Sig	Sig
Total score	55.98	10.63	15.38	5.34	48.78	10.54	0.000*	0.000*
AR	21.35	5.56	2.55	2.09	7.13	3.62	0.000*	0.000*
MR	4.65	2.73	3.25	1.66	5.15	7.25	0.648	0.094
BI	2.93	1.93	1.80	1.57	2.50	2.06	0.025*	0.003*
OJ	8.40	2.93	2.48	2.21	9.35	3.35	0.072	0.000*
OC	2.58	2.34	3.93	2.56	12.03	3.99	0.000*	0.000*
OR	14.28	4.77	1.33	1.79	13.35	5.04	0.067	0.000*
IC	1.55	3.51	0.03	0.16	0.38	0.98	0.037*	0.033*

SD, standard deviation; *Sig*, significance; *AR*, alignment; *MR*, marginal ridges; *BI*, buccolingual inclination; *OJ*, overjet; *OC*, occlusal contacts; *OR*, occlusal relationship; *IC*, interproximal contacts.
*Paired *t* test was significant at the 0.05 level (2-tailed).

Table IV. Total number of aligners and refinement percentage

	Class I		Class II		
No. of aligners	Mean	SD	Mean	SD	Sig
Initial set	22.73	5.45	29.03	10.75	0.002*
Second set	13.10	6.46	21.23	12.06	0.000*
Total	35.83	9.91	50.25	20.72	0.000*
Refinement (%)	58.08	26.00	73.40	29.72	0.016*

SD, standard deviation; *Sig*, significance.
*Independent *t* test was significant at the 0.05 level (2-tailed).

aligners was higher in the Class II malocclusion group and the refinement percentage, as shown in Table IV. Patients with Class II malocclusion required significantly more initial aligners as well as a greater percentage at refinement than those with Class I malocclusion, indicating longer treatment time.

The mean AP percentage change was 1.25% and 6.8% in Class I and Class II malocclusion groups, respectively (Table V). The mean overbite percentage change was 28.8% in the Class I malocclusion group and 38.9% in the Class II malocclusion group.

The ABO measurements were compared between the 2 groups at T1, T2A, and T2B (Table VI). The Class II initial malocclusion demonstrated a greater need for improvement in overbite, marginal ridges, overjet, and occlusal relationships. The predicted ClinCheck occlusion demonstrated higher overall ABO scores for patients with Class II malocclusion, with higher predicted scores found in marginal ridges, occlusal contacts, and occlusal relationships than those with Class I malocclusion. The

Table V. AP and overbite millimetric measurements

	Class I		Class II		
Variables	Mean	SD	Mean	SD	Sig
Anterior posterior					
Needed (mm)	0.23	0.41	3.48	1.26	0.000*
Predicted (mm)	0.23	0.41	3.29	2.46	0.000*
Achieved (mm)	0.01	0.33	0.25	0.63	0.039*
Achieved (%)	1.25	32.99	6.80	18.90	0.359
Overbite					
Needed (mm)	1.05	1.14	2.59	1.58	0.000*
Predicted (mm)	1.08	1.12	2.75	1.56	0.000*
Achieved (mm)	0.48	0.68	1.23	1.28	0.002*
Achieved (%)	28.84	35.99	38.93	39.30	0.235

SD, standard deviation; *Sig*, significance.
*Independent *t* test was significant at the 0.05 level (2-tailed).

achieved posttreatment occlusion scores were significantly higher in the Class II malocclusion group, with the only significant differences observed in overjet and occlusal relationships—no other differences were observed.

Table VII displays the percentage accuracy of tooth movements found in patients in both Class I and Class II malocclusion groups. The percentage achieved is calculated using 2 different gold standards: the predicted ClinCheck and a total ABO score without any point deductions.

Any tooth movement that showed no improvement or became worse with treatment was designated as 0% accurate. The larger the difference between the 2 percentage achieved models, the more the ClinCheck failed in recognizing and correcting the malocclusion for that particular tooth movement. The differences observed between the ClinCheck-standard percentage achieved and the ABO standard percentage achieved illustrates an objective observation: the ClinCheck model does not predict a flawless occlusion according to the rigorous standards established by the ABO.

DISCUSSION

Previous studies have evaluated the accuracy of tooth movements with Invisalign,[21,22] but the results may be skewed because accuracy was measured by evaluating tooth movements at debonding, not after completing treatment with the initial set of aligners. The current study was developed to produce a true understanding of the achieved individual tooth movements and comparing them with their predicted models over a finite period. As a result, it can be expected for the current study to have different scores.

This study showed improvements in the total ABO scores, but a significant difference was observed when

Table VI. Intergroup independent *t* test statistics

	Class I		Class II		
Variables	*Mean*	*SD*	*Mean*	*SD*	*Sig*
T1					
Total score	35.25	8.84	55.98	10.63	0.000*
AR	20.85	6.27	21.35	5.56	0.707
MR	3.10	2.10	4.65	2.73	0.006*
BI	2.30	1.62	2.93	1.93	0.121
OJ	3.35	2.68	8.40	2.93	0.000*
OC	2.90	2.64	2.58	2.34	0.562
OR	0.65	1.05	14.28	4.77	0.000*
IC	2.13	4.92	1.55	3.51	0.549
T2A					
Total score	12.00	5.35	15.38	5.34	0.006*
AR	2.75	1.63	2.55	2.09	0.634
MR	2.10	1.50	3.25	1.66	0.002*
BI	1.95	1.62	1.80	1.57	0.675
OJ	2.40	2.69	2.48	2.21	0.892
OC	2.68	2.46	3.93	2.56	0.029*
OR	0.13	0.34	1.33	1.79	0.000*
IC	0.15	0.95	0.03	0.16	0.416
T2B					
Total score	27.53	8.42	48.78	10.54	0.000*
AR	7.30	3.74	7.13	3.62	0.832
MR	3.10	2.24	5.15	7.25	0.094
BI	2.40	1.77	2.50	2.06	0.816
OJ	3.13	2.78	9.35	3.35	0.000*
OC	10.60	4.11	12.03	3.99	0.120
OR	0.73	1.01	13.35	5.04	0.000*
IC	0.30	0.91	0.38	0.98	0.724

SD, standard deviation; *Sig,* significance; *AR,* alignment; *MR,* marginal ridges; *BI,* buccolingual inclination; *OJ,* overjet; *OC,* occlusal contacts; *OR,* occlusal relationship; *IC,* interproximal contacts.
*Independent *t* test was significant at the 0.05 level (2-tailed).

Table VII. Mean percentage accuracy of tooth movements

	Class I		Class II	
Variables	*% Achieved (CC)*	*% Achieved (ABO)*	*% Achieved (CC)*	*% Achieved (ABO)*
Total score	33.20	21.90	17.73	12.86
AR	74.86	64.99	75.64	66.60
MR	0	0	0	0
BI	0	0	38.05	14.68
OJ	23.16	6.57	0	0
OC	0	0	0	0
OR	0	0	7.18	6.51
IC	92.40	85.92	76.98	75.48

CC, ClinCheck; *AR,* alignment; *MR,* marginal ridges; *BI,* buccolingual inclination; *OJ,* overjet; *OC,* occlusal contacts; *OR,* occlusal relationship; *IC,* interproximal contacts.

compared with the predicted ClinCheck occlusion between groups. The total predicted scores, as well as marginal ridges, occlusal contacts, and occlusal relationships were significantly higher in patients with Class II malocclusion. This phenomenon may indicate that Class II treatment with Invisalign potentially compromises the result compared with Class I treatment. Alternatively, there may be too many simultaneous movements during treatment for patients with Class II malocclusion, requiring the software to prioritize certain tooth movements over others. No improvements were observed in AP correction in patients with Class II malocclusion when the correction was attempted with Class II elastics with no specific verification of compliance after the average duration of 7 months required to complete treatment with the initial set of aligners. The amount of AP correction in patients with Class II malocclusion was only 6.8% of the predicted amount.

Whether failure to achieve the predicted amount of AP correction in patients with Class II malocclusion is due to compliance or inadequate time allotted for such movement, the result in either case is that further Class II correction would require additional refinements and increased treatment duration. The clinical significance, therefore, has implications for both patient management and practice management. Furthermore, if the amount of AP correction was limited, at best, under the direct supervision of a trained orthodontic specialist, then one may assume that a direct-to-consumer product might provide no further significant improvements to an unsupervised patient.

Figure 2 illustrates the Invisalign Class II correction by distalization. Biomechanically, as a posterior force is placed on the molars during distalization, an equal and opposite force is placed on the anterior teeth. This results in an increased overjet if Class II elastics are not worn, which was observed between the initial overjet (mean 8.40 mm) and the achieved posttreatment overjet (mean 9.35 mm). However, these values were not shown to be statistically different from one another. Rossini et al[14] showed that AP movement via maxillary molar distalization was highly predictable (88% accuracy) when at least 1.5 mm of translation was prescribed. These findings and ours cannot be directly compared because the previous study used lateral cephalograms to evaluate molar movements, which may have induced measurement errors because of the superimposition of contralateral molars. In addition, the previous study did not have a control group.

ABO scores increased in both groups because of a lack of occlusal contacts. Figure 3 illustrates an occlusal view of the occlusal contacts before and after treatment with the initial set of aligners. It is unknown if these findings are transient and diminish upon settling or if they require additional refinements for correction. If it is the latter, then the force system applied to the teeth

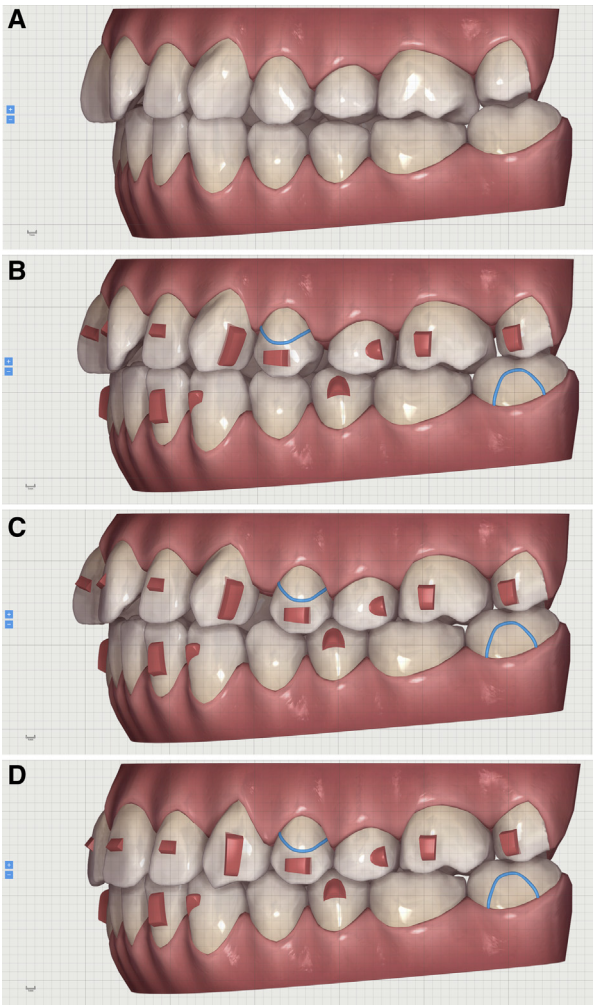

Fig 2. Class II correction by distalization from ClinCheck prediction: **A,** before distalization; **B,** progress (noted a space between maxillary first and second premolar); **C,** progress (noted a space between maxillary canine and first premolar); **D,** after distalization.

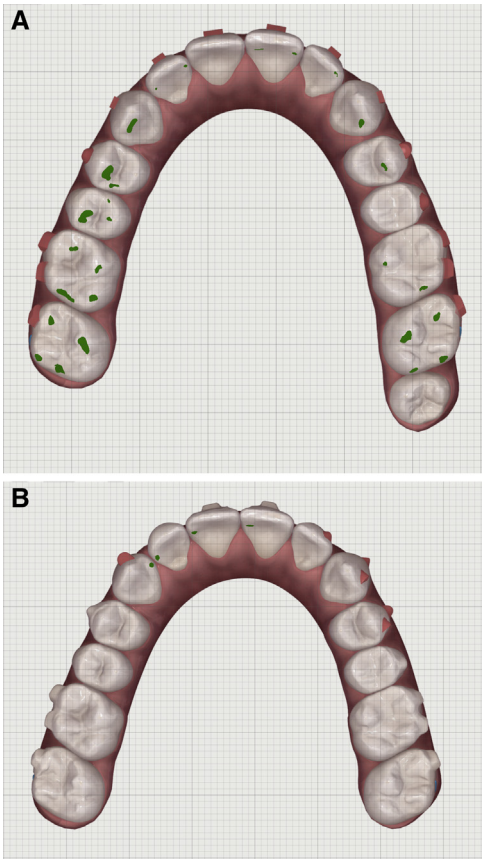

Fig 3. Occlusal contacts: **A,** before treatment; **B,** after treatment.

is creating a new problem that requires additional treatment, and thus, it is reducing efficiency. Figure 4 illustrates a buccal view of the posterior open bite created after treatment with the initial set of aligners.

The methodology of this study was designed to produce parity between groups with an equal number of patients with Class I and Class II malocclusion and to exclude the influence from the provider experience, growth, gender, age, and overcorrection of tooth movements within the sample. However, the following factors may have contributed to the results observed:

1. There was no control over the difficulty of the malocclusion in both groups. In this study, despite there being no differences in the amount of overbite correction achieved between the groups, there was a greater need for overbite correction in the Class II malocclusion group. This may have been due to the extrusion of incisors owing to the lack of incisal contacts in patients with large overjet.

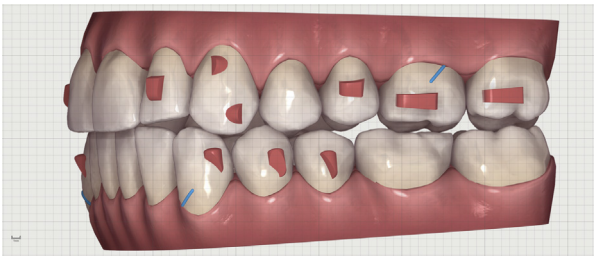

Fig 4. Buccal view of posterior open bite.

2. If patients had previous orthodontic treatment, then there would be expected differences in the amount of correction needed for additional tooth movements. This phenomenon was observed in the amount of overbite correction needed and initial marginal ridge heights. It would be expected that previous orthodontic treatment would correct these tooth movements because the first step in treatment involves leveling of the dentition. This may have accounted for the differences observed between the 2 groups in the initial malocclusion.
3. The clinical preferences of the Invisalign provider were unknown. Though preferences in magnitude and duration of elastics are unique to each provider, all the cases examined in this study were from a top 1% Invisalign provider, ensuring a level of consistency, experience, and judgment in orthodontic treatment.
4. There was no means to verify if compliance with aligner wear was a contributing factor. In addition, there was no means to evaluate any possible centric occlusion–centric relation discrepancy unless made known in the clinical notes to the Invisalign technician.
5. The number and shape of attachments placed on teeth may affect aligner tracking and tooth movement. Furthermore, any changes made to the automated software could have influenced the threshold that triggers the placement of the "appropriate" attachment.
6. The ABO MGS was intended for plaster casts in-hand. According to one study, the average scores for alignment and buccolingual inclination were found to be different between manual and digital grading.[23] Despite the principal investigator being calibrated by an ABO Director, the results of the study may differ from those found if the measurements were performed with cast in-hand.

CONCLUSIONS

1. Significant improvements in total ABO score, alignment, and interproximal contacts were observed in both Class I and Class II malocclusion groups.
2. No improvements were observed in AP correction in patients with Class II malocclusion when correction was attempted with Class II elastics. The amount of overbite correction achieved was 28.8% and 38.9% of the predicted amounts in patients with Class I and Class II malocclusion, respectively.
3. Additional refinements and increased treatment duration would be required to achieve an ideal occlusion. As a result, the orthodontic specialist should be aware of the potential patient management and practice management implications.
4. The ClinCheck predicted an ABO-quality occlusion for the entire sample; however, all posttreatment occlusions failed to meet ABO standards in the Class II malocclusion group.

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