Predicted and achieved overjet and overbite measurements with the Invisalign appliance: *a retrospective study*

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ABSTRACT

Objectives: To determine whether achieved outcome regarding overjet and overbite matched the predicted outcome following treatment with Invisalign (Align Technology, San Jose, Calif) aligner appliances.

Materials and Methods: Data including pretreatment, predicted and achieved overjet, and overbite measurements provided by Align's digital treatment facility, ClinCheck Pro, were evaluated. Descriptive statistics, Mann-Whitney *U*-test, and Wilcoxon rank-sum intraclass correlation (ICC) test results were calculated.

Results: From an initial sample of 600, 355 adult patients satisfied the inclusion and exclusion criteria. ICC scores for data input were excellent. Median (interquartile range [IQR]) age was 30.14 (23.33, 39.92) years and most (n = 259; 72.95%) were women. Almost one-third (n = 101; 28.45%) had undergone extraction as part of their treatment. More aligners were prescribed in the initial digital treatment plan for patients (median, 44; IQR: 35, 51.5; minimum, 17; maximum, 92) undergoing extractions as part of their orthodontic treatment than those who were not (median, 24; IQR: 18.25, 32; minimum, 13; maximum, 85) ($P < .0001$). Planned changes in overjet differed significantly from achieved outcomes ($P < .001$). Planned increases in overbite resulted in up to more than twice (222.72%) as much increase than predicted. Planned reduction of overbite achieved 8.69% of its predicted reduction in extraction cases.

Conclusions: Achieved overjet and overbite measurements differed significantly from the predicted outcomes at the end of an initial sequence of aligners. Planned increases in overbite resulted in greater overbite correction than predicted, particularly in extraction cases. Planned overbite reduction was challenging, especially in patients with extractions. (*Angle Orthod*. 2024;94:3–9.)

KEY WORDS: Clear aligner therapy; Invisalign; Orthodontic treatment outcomes; Overbite; Overjet

INTRODUCTION

Clear aligner therapy (CAT) is an accepted part of modern orthodontic practice.[1] Frequently cited advantages include less chair time, fewer office visits, easier oral hygiene, and an esthetic alternative to fixed appliance therapy (FAT).[2] Recent studies have indicated that Invisalign is one of the most used CAT appliances globally.[1,3,4] Invisalign (Align Technology, San Jose, Calif) uses three-dimensional technology to facilitate treatment planning and aligner fabrication processes.[2] Align provides a digital interface, ClinCheck Pro, which enables the clinician to formulate a digital treatment plan (DTP). Once the clinician approves the DTP, Align manufactures the sequence of aligners and they are sent to the clinician.[5] Several investigations indicated that the initial DTP is routinely followed up by one or more refinement plans in which additional series of aligners are prescribed to achieve treatment objectives.[6,7]

The DTP process also facilitates the provision of the predicted treatment outcome. Align Technology provides the pretreatment and predicted intra-arch and interarch occlusal measurements, including initial and predicted overjet and overbite measurements, as part of

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its DTP processes. The predicted measurements can, therefore, be compared with achieved clinical outcomes, and a determination of the level of success in obtaining treatment objectives can be made. Several studies, using indices such as the Peer Assessment Rating (PAR), the American Board of Orthodontics Model Grading System (ABO-MGS), the American Board of Orthodontics Objective Grading System (ABO-OGS), and metrology software, indicated that that the predicted treatment outcome is rarely achieved.[8–13] The use of overjet and overbite measurements provided by Align's ClinCheck Pro facility for the assessment of treatment outcomes, however, is limited in the literature. These data can provide additional information regarding the accuracy of Invisalign treatment in the management of overjet and overbite. In addition, this information can assist clinicians in taking corrective measures during Invisalign treatment.

The aim of this study was to determine whether the achieved outcome regarding overjet and overbite matched the predicted outcome after an initial sequence of Invisalign aligners. The null hypothesis was that there would be no differences between the achieved and predicted overjet and overbite measurements.

MATERIALS AND METHODS

Ethical approval for this retrospective study was granted by the University of Adelaide's Human Research Ethics Committee. Data for the study were acquired from the Australasian Aligner Research Database (AARD). AARD comprises information regarding approximately 14,000 patients who have undergone or are undergoing CAT with the Invisalign appliance. The patients are provided by 12 experienced orthodontists, each of whom has treated at least 300 patients. All patients treated with Invisalign by the orthodontists are contained within the database to minimize selection bias. In addition, all patients provided informed consent for their information to be used for research purposes.

A total of 600 patients (50 from each of the orthodontists) was chosen via a random sequence of integer generator (https://www.random.org/sequences/).

Inclusion Criteria

- Age 18 years or older.
- Treatment with the Invisalign appliance only, no earlier than 2018.
- Dual arch treatment only.
- Patients with a complete permanent dentition.
- Patients compliant with prescribed Invisalign wear protocols as reported by the treating orthodontist.
- Availability of the accepted initial ClinCheck Pro data and the accepted initial refinement ClinCheck

Pro data to enable the recording of data required for the study.

Exclusion Criteria

- Noncompliance with the aligner wear protocol.
- Combined orthodontic treatment and orthognathic surgery.
- Craniofacial syndromes.
- Bone metabolism altering medications, such as bisphosphonates.

The measurement values for overjet and overbite were obtained from the data provided in each patient's initial accepted initial DTP (initial and predicted overjet and overbite measurements) and the first refinement scan (achieved values) via the ClinCheck Pro facility. Additional data, including the number of DTPs before acceptance by the orthodontists and the number of aligners prescribed in the initial accepted DTP were also obtained via ClinCheck Pro.

The following deidentified information was documented on a Microsoft Excel (Microsoft, Redmond, Wa) spreadsheet:

1. Patient sex and age at the commencement of treatment.
2. The number of DTPs prior to acceptance by the orthodontist.
3. The number of aligners prescribed in the initial accepted DTP.
4. The number of extractions (if carried out) per patient.
5. The overjet and overbite measurements at the commencement of treatment provided in the accepted DTP.
6. The predicted overjet and overbite measurements at the commencement of treatment provided in the accepted DTP.
7. The achieved overjet and overbite measurements at the end of treatment as provided by the DTP for the first refinement scan.

Statistical Analysis

Descriptive statistics were computed via GraphPad Prism 9.0 (GraphPad Software Inc., La Jolla, Calif). The normality of the study groups and subgroups were evaluated with the Shapiro-Wilk test. As all groups and subgroups had nonparametric distributions, the Mann-Whitney U-test and Wilcoxon rank-sum test were used to determine significant differences between groups and subgroups. The data of 50 randomly chosen patients were checked via intracorrelation coefficient (ICC) testing to assess intrarater reliability in data input to the Excel spreadsheet.
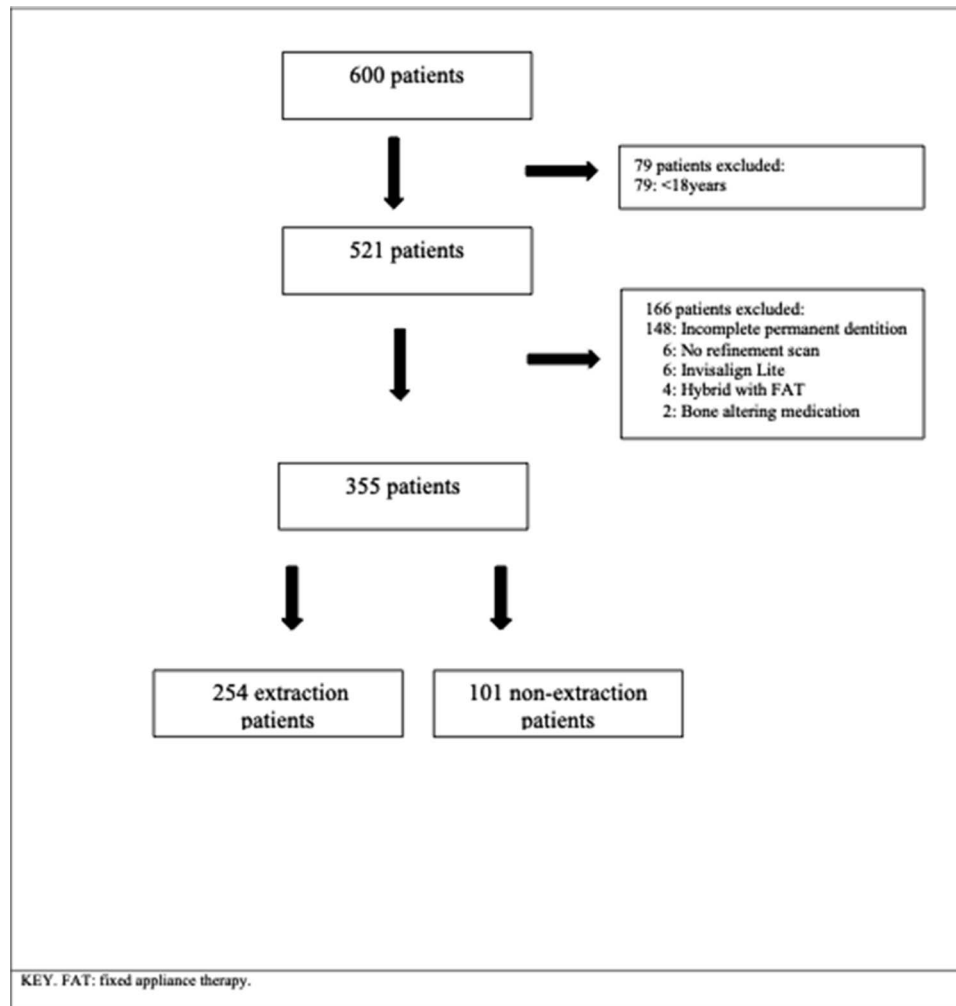
Figure 1. Flowchart for patient selection.

RESULTS

Figure 1 shows that 355 patients satisfied the inclusion and exclusion criteria. Table 1 shows that most patients were women. No significant differences ($P = .42$) between the ages of the men and women were documented.

A median of two extracted teeth per patient in the extraction group (IQR: 1, 4; minimum [min], 1; maximum [max], 4) was recorded. More teeth were extracted in the upper arch (median, 2; IQR: 1, 2) compared with the lower arch (median: 0; IQR: 0, 2) ($P < .001$). All extracted teeth were either first or second permanent premolars aside from two permanent canines. There was a median of 3 (IQR: 2, 5; min, 1; max, 14) DTPs prior to acceptance by the orthodontist. There were more DTPs prior to acceptance for patients (median: 4; IQR: 3, 5; min, 1; max, 14) undergoing extractions as part of their orthodontic treatment than those who were not (median: 3; IQR: 2, 4; min, 1; max, 4) ($P < .0001$).

A median of 29 (IQR: 20, 40; min, 13; max, 92) aligners were prescribed by the orthodontist in the initial accepted DTP. There were more aligners prescribed in the initial DTP for patients (median: 44; IQR: 35, 51.5; min, 17; max, 92) undergoing extractions as part of their orthodontic treatment than those who were not (median: 24; IQR: 18.25, 32; min, 13; max, 85) ($P < .0001$).

Table 2 shows that 11 patients had no planned changes in overjet in the accepted DTP. Table 3 shows that five patients had no planned changes in overbite in the accepted DTP. Table 4 indicates that, in patients where a decrease in overjet was planned, the median achieved overjet was significantly less than the median predicted overjet in patients undergoing nonextraction treatment (2.1 mm vs 3.0 mm; $P < .0001$) and in patients undergoing extraction treatment (1.9 mm vs 3.1 mm; $P < .0001$). Table 5 shows that, in patients for whom a decrease in overbite was planned, the median achieved overbite was significantly less than the median predicted overbite in patients undergoing nonextraction treatment (1.4 mm

Table 1. Demographic Statistics (N = 355)

			Treatment Modality	
		Total	Nonextraction, n = 254	Extraction, n = 101
Age, y; median (IQR) (min, max)[a]				
Overall		30.14 (23.33, 39.92) (18.0, 76.08)	32.21 (24.50, 41.15) (18.00, 76.08)	26.67 (21.67, 33.5) (18.0, 63.92)
Male		30.08 (23.33, 37.46) (18.08, 68.08)	31.33 (25.75, 39.00) (18.33, 68.08)	23.71 (20.5, 32.42) (18.08. 54.33)
Female		30.13 (23.39, 41.11) (18.0, 76.08)	32.33 (24.38, 41.75) (18.00, 76.08)	27.42 (22.92, 33.67) (18.0, 63.92)
Sex, n (%)				
Male		96 (27.04)	66 (25.99)	30 (29.7)
Female		259 (72.95)	188 (74.01)	71 (70.3)
Overjet, n (%)				
<2 mm		66 (18.59)	51 (20.07)	15 (14.85)
2–4 mm		172 (48.45)	139 (54.72)	33 (32.67)
>4 mm		117 (32.96)	64 (25.21)	53 (52.47)
Overbite, n (%)				
<2 mm		114 (32.25)	84 (33.07)	30 (29.70)
2–4 mm		124 (34.92)	85 (33.46)	39 (38.61)
>4 mm		116 (32.83)	84 (33.07)	32 (31.69)

[a] IQR indicates interquartile range; min, minimum; and max, maximum.

vs 2.7 mm; $P < .0001$) and in patients undergoing extraction treatment (1.25 mm vs 3.35 mm; $P < .0001$). Table 6 illustrates that the achieved increase in overbite more than doubled (222%) that predicted in patients where extractions were carried out as part of the orthodontic treatment plan.

ICC scores for data input were high, ranging from 0.98 to 1.

DISCUSSION

This study was among the first to comprehensively investigate whether the measurement values provided by Invisalign regarding predicted overjet and overbite matched the achieved outcomes after an initial sequence of aligners. The findings indicated that the achieved overjet was approximately half of the predicted overjet, whereas only one-third of a planned decrease in overbite was achieved. Consequently, the null hypothesis was rejected.

The study comprised 355 patients compared with 20–355 in similar investigations.[5,6,9,10,14–16] Patients younger than the age of 18 years were excluded to minimize growth as a potential confounding factor in the findings. Most patients were women, and the median age was 30.14 years, which corresponded with the patient demographic observed in other CAT studies.[5,6,9,16,17] A large sample was randomly chosen to obtain a representative sample of patients treated with Invisalign and to overcome the limited available data on which to base a power calculation.[18]

The patients in the extraction group required more DTPs before acceptance by the orthodontist and more aligners within the DTP than those in the nonextraction group. This suggested the greater complexity involved in obtaining the orthodontists' desired treatment outcomes in extraction cases.[6,17]

The current study was the first to compare predicted and achieved overjet and overbite treatment outcomes comprehensively with the Invisalign appliance using

Table 2. Pretreatment, Predicted, and Achieved OJ Measurements (N = 355)[a]

		Pretreatment	Predicted	Achieved	P[b]
Planned OJ ↑	Median	1.8	2.7	2.3	
(n = 90)	IQR	1.175, 2.6	2.2, 3.7	1.775, 3.6	.0003*
	Min, max	−2, 7.3	1.1, 8.4	0.7, 8.4	
Planned OJ ↓	Median	3.8	2.0	3.0	
(n = 254)	IQR	3, 5.025	1.6, 2.6	2.3, 4.0	<.0001*
	Min, max	1.5, 14.7	0.2, 4.5	0.8, 9.0	
No OJ ↑↓ planned	Median	2.0	2.0	2.1	
(n = 11)	IQR	1.8, 2.3	1.8, 2.3	1.9, 2.6	.5781
	Min, max	1.3, 2.8	1.3, 2.8	1.1, 2.8	

[a] ↑ = increase; ↓ = decrease; No OJ ↑↓ = no change. IQR indicates interquartile range; Min, minimum; max, maximum; and OJ, overjet.
[b] Wilcoxon rank-sum test.
* $P < .05$, statistically significant.

Table 3. Pretreatment, Predicted, and Achieved OB Measurements (N = 355)[a]

		Pretreatment	Predicted	Achieved	P[b]
Planned OB ↑	Median	0.35	1.5	1.6	
(n = 68)	IQR	−0.4, 1.075	1.2, 2.0	0.625, 2.5	.8139
	Min, max	−4.3, 2.9	−0.4, 3.9	−3.5, 6.1	
Planned OB ↓	Median	3.7	1.4	2.9	
(n = 282)	IQR	2.5, 4.8	0.8, 2.0	2.0, 3.9	<.0001*
	Min, max	0, 9.3	−0.1, 7.0	0, 8.6	
No OB ↑↓ planned	Median	1.1	1.1	1.3	
(n = 5)	IQR	0.1, 1.55	0.1, 1.55	0.75, 1.95	.6875
	Min, max	0, 1.8	0, 1.8	0.5, 2.6	

[a] ↑ = increase; ↓ = decrease; No OB ↑↓ = no change. IQR indicates interquartile range; Min, minimum; max, maximum; and OB, overbite.
[b] Wilcoxon rank-sum test.
* P < .05, statistically significant between predicted and achieved.

data from Align's digital interface, ClinCheck Pro. It reflected the findings from studies that have assessed and compared the predicted and the achieved outcomes resulting from treatment with the Invisalign appliance using a range of alternative methodologies.[8–13] Several studies, for example, using PAR, ABO-OGS, or ABO-MGS, indicated that overjet measurements worsened or did not improve with Invisalign treatment.[14,19–21] However, with improved technology and changing protocols, more recent investigations indicated some improvement in overjet measurements with Invisalign treatment.[6,13] It must be noted, nevertheless, that the present study aimed to assess the achieved outcomes and compare them with the outcomes predicted by the DTP after the initial series of aligners. It included cases where a reduction or increase in overjet to achieve a Class I incisor relationship was not necessarily a targeted treatment outcome, so it may represent a more real-world cohort of case types.[22] Specific data regarding planned overjet increase (usually patients presenting with a Class III incisor relationship) are limited in the literature.[23] The findings of the present investigation appear to suggest that a planned increase in overjet was closer to the predicted outcome than in patients where a reduction in overjet was prescribed. This may be attributed to the relatively more modest overjet changes required in this regard.

The achieved overbite reduction in nonextraction patients was 45.83% of that predicted. This compared to the 39.2%–45% recorded in similar studies.[10,24,25] However, planned overbite reduction in extraction patients achieved only 8.69% of that predicted. This supports the concerns reported in the literature regarding the reduction of (particularly deep) overbites.[1,23] Previous studies indicated that specific tooth movements incorporated into the DTP to reduce an overbite resulted in wide variance in the specific movements predicted.[9,24] The apparent challenges in reducing deeper overbites with the Invisalign appliance suggest that a hybrid approach involving the use of CAT and FAT may result in more effective overbite reduction.[7]

By contrast, the Invisalign appliance appeared to be more effective in increasing overbites in patients where a planned increase was prescribed. A median increase in overbite of 1.05 mm was observed in nonextraction patients where a planned overbite increase was prescribed. This compared with a median overbite increase of 1.5 mm in anterior open bite cases reported in a 2017 study.[5] The posterior bite-block effect and relative intrusion of the posterior teeth due to the interocclusal position of the Invisalign appliance has been suggested as a principal mechanism for overbite reduction. However, overbite increased by

Table 4. Pretreatment, Predicted, and Achieved OJ Measurements of Patients Where Changes in OJ Were Planned (n = 344)[a]

		Nonextraction, n = 79				Extraction, n = 11			
		Pretreatment	Predicted	Achieved	P[b]	Pretreatment	Predicted	Achieved	P[b]
Planned OJ ↑	Median	1.9	2.8	2.5		0.8	2.5	2.1	
(n = 90)	IQR	1.3, 2.6	2.2, 3.7	1.8, 3.6	.0009*	−0.5, 1.2	2.2, 2.7	1.6, 2.3	.2070
	Min, Max	−1.7, 7.3	1.1, 8.4	0.7, 8.4		−2.0, 3.7	1.8, 5.2	1.1, 3.8	
		Nonextraction, n = 169				Extraction, n = 85			
Planned OJ ↓	Median	3.6	2.1	3.0		4.5	1.9	3.1	
(n = 254)	IQR	2.9, 4.65	1.65, 2.6	2.3, 3.8	<.0001*	3.15, 6.7	1.55, 2.4	2.2, 4.2	<.0001*
	Min, Max	1.5, 9.2	0.6, 4.5	0.8, 6.6		1.7, 14.7	0.20, 3.6	1.3, 9.0	

[a] ↑ = increase; ↓ = decrease. IQR indicates interquartile range; Min, minimum; max, maximum; and OJ, overjet.
[b] Wilcoxon rank-sum test.
* P < .05, statistically significant between predicted and achieved.

Table 5. Pretreatment, Predicted, and Achieved OB Measurements of Patients Where Changes in OB Were Planned (N = 350)[a]

		Nonextraction, n = 52				Extraction, n = 16			
		Pretreatment	Predicted	Achieved	P[b]	Pretreatment	Predicted	Achieved	P[b]
Planned OB ↑	Median	0.45	1.65	1.5		0.05	1.15	2.5	
(n = 68)	IQR	−0.375, 1.275	1.3, 2.08	0.5, 2.0	.0122*	−0.5, 0.7	0.325, 1.85	1.375, 3.15	.0206*
	Min, max	−4.3, 2.4	−0.2, 3.4	−3.5, 4.0		−3.2, 2.9	−0.4, 3.9	0.2, 6.1	
		Nonextraction, n = 200				Extraction, n = 82			
Planned OB ↓	Median	3.8	1.4	2.7		3.55	1.25	3.35	
(n = 282)	IQR	2.6, 4.7	0.8, 2.0	1.9, 3.6	<.0001*	2.3, 5.0	0.775, 1.8	2.2, 4.5	<.0001*
	Min, max	0, 9.3	−0.8, 7.0	0, 8.6		0.3, 9.0	−1.0, 3.1	0.4, 7.7	

[a] ↑ = increase; ↓ = decrease. IQR indicates interquartile range; Min, minimum; max, maximum; and OB, overbite.
[b] Wilcoxon rank-sum test.
* P < .05, statistically significant between predicted and achieved.

more than double in those patients who had extractions as part of their CAT, which is likely to be clinically significant. This indicated that incisor retroclination may have a significant contribution regarding the increase in overbite in extraction cases.[26]

The limitations of this study are acknowledged. The potential risk of selection bias associated with retrospective studies, however, was reduced by the application of strict inclusion and exclusion criteria to a large sample of patients. The assessment of overjet and overbite changes related to the initial series of aligners only, and not the end of treatment. Nevertheless, this corresponded with the methodology adopted in several similar studies.[8–10,14–16] Although previous studies have indicated acceptable accuracy of ClinCheck Pro measurements, further research is required to determine the reliability of overjet and overbite values provided by the digital interface.[11,27,28]

Strengths of this investigation included the high ICC scores and the evaluation of patient data from 12 orthodontists, which increased the generalizability of the findings. This contrasted with the one-to-three clinicians used in comparable studies.[5,6,14,19,20] In addition, patients with a wide range of overjet and overbite measurements were assessed.

Table 6. Percentage Comparison of Achieved vs Predicted OJ and OB Measurements[a]

		Treatment Modality	
	Total % change	Nonextraction % change	Extraction % change
OJ ↑	55.55	66.67	76.47
OJ ↓	44.44	40.00	53.84
OB ↑	108.69	87.5	222.72
OB ↓	34.78	45.83	8.69

[a] ↑ = increase; ↓ = decrease. <100% indicates a shortfall; >100% indicates "overcorrection." % change calculated by dividing the difference between the pretreatment and achieved measurement by the difference between the pretreatment and predicted measurement × 100. OB indicates overbite; OJ, overjet.

The present study aimed to investigate whether the achieved outcomes regarding overjet and overbite matched the outcomes planned by experienced orthodontists prior to commencing treatment. The findings provided new data regarding the effectiveness of the Invisalign appliance in managing overjet and overbite. These data can assist the orthodontist in taking additional measures, such as the synchronous use of FAT, for the management of some malocclusions. Future prospective studies, however, are required to investigate the aligner material, software, biological, patient, and clinician factors that resulted in the wide variation from the values predicted in the DTP processes.

CONCLUSIONS

From the sample of patients evaluated in the present study, several conclusions can be made.

- Significantly more aligners are prescribed in the initial DTP for patients undergoing extractions as part of their orthodontic treatment than those who are not.
- Achieved overjet and overbite measurements do not match the predicted outcomes at the end of an initial sequence of aligners.
- Only 44% to 56% of planned overjet changes are achieved.
- Planned increases in overbite result in greater overbite correction than predicted, particularly in extraction cases.
- Planned overbite reduction is challenging, especially in patients with extractions.

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