



Planned and achieved overjet and overbite changes following an initial series of Invisalign® aligners: A retrospective study of adolescent patients

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Keywords

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Summary

Objective > The aim of the present study was to compare the changes in overjet and overbite measurements achieved in adolescent patients following an initial series of Invisalign® aligners (Align Technology, San Jose, California) with those planned by orthodontists via its ClinCheck® digital treatment planning facility.

Methods > Data provided by Align regarding patients who had completed an initial series of Invisalign® aligner treatment and were less than 18-years old were assessed in relation to pre-treatment, planned and achieved overjet and overbite measurements. Descriptive statistics, Wilcoxon rank-sum, Mann Whitney calculations were computed.

Results > A total of 290 patients satisfied inclusion criteria. The median (interquartile range (IQR)) age was 14.17 (13,15.42) years. The median achieved overjet and overbite changes were less than those planned ($p < 0.01$) with 53.33% of the planned median overjet increase achieved and 52.94% of planned median overjet reduction achieved. Additionally, 58.33% of the planned median overbite increase was achieved and 55.55% of the planned median overbite reduction was achieved. A total of 21.52% patients recorded no change or an increase from pre-treatment to the achieved overjet where reduction was planned, whereas 41.67% recorded no change or a reduction in overjet where increase was planned. A total of 18.72% recorded no change or an increase in overbite where reduction was planned, whereas 20.75% recorded no change or a reduction in overbite where increase was planned.

Conclusions > Less than 60% of the planned overjet and overbite changes per patient were achieved. Between 18.72 and 41.67% of patients experienced no change or changes in overjet and overbite in the opposite direction to that planned. This is likely to be clinically significant.

Introduction

Clear aligner therapy (CAT) is a common treatment option among orthodontists, with evidence indicating that it is being increasingly used to address malocclusion in adolescent patients [1,2]. Recent surveys suggest that Invisalign® (Align Technology, San Jose, California, USA) is one of the leading prescribed CAT appliances [2,3]. Orthodontists use a software facility provided by Align Technology, called ClinCheck®, to enable the creation of a digital treatment plan (DTP) for patients. The facility also provides information and numerical data regarding pre-treatment and planned tooth positions and occlusal features, such as overjet (OJ) and overbite (OB) measurements, as part of this process [4]. Once a DTP is accepted by the orthodontist, a(n initial) series of aligners is manufactured and sent to the orthodontist [4].

Several studies have indicated that achieved outcomes following wear of an initial series of aligners vary from the changes planned by the orthodontist via the facility and that one or more series of additional (refinement) aligners are still required to address initial treatment objectives [4–11]. A recent study showed, for example, that planned increases in overbite in adult patients undergoing CAT with prescribed orthodontic extractions resulted in more than twice the predicted increase after wear of an initial series of aligners [11]. In addition, an investigation comparing intrusion of mandibular incisors in adolescents with adults showed that 63.5% of the planned intrusion with the Invisalign® appliance occurred in the adolescent sample [12]. Commonly cited reasons for differences in planned and achieved outcomes are challenges associated with particular tooth movements, sub-optimal patient compliance with CAT wear protocols and inadequate CAT technological processes [4,5,7,13].

Virtually all of these studies, however, related to adult patients who were the original intended patient demographic of the Invisalign® appliance [14]. The literature appears to be limited in relevant studies pertaining to patients who had not reached adulthood [12,15] – even though a recent survey indicated that almost 65% of orthodontists 'mostly' or 'sometimes' treated adolescents/teenage patients with CAT [2]. Data in this regard are important as it provides clinicians, CAT appliance manufacturers, materials' scientists, and patients with information regarding relevant characteristics of the Invisalign® appliance. The aim of the present study was to compare the changes in OJ and OB measurements achieved in adolescent patients following an initial series of Invisalign® aligners (Align Technology, San Jose, California) with those planned by orthodontists via its ClinCheck® digital treatment planning facility. The null hypothesis was that there is no difference in the achieved changes compared with those planned by the orthodontist via the facility.

Material and methods

Ethical approval for this retrospective investigation was granted by the University of Adelaide Human Research Ethics Committee.

The patient data assessed in this study were extracted from the Australasian Aligner Research Database (AARD). The database contains information related to all patients treated with the Invisalign® appliance by 17 orthodontists in three countries. All orthodontists are experienced in treatment with the appliance, having treated at least 300 patients over a minimum of 10 years with it.

An initial screening phase involved the exclusion of all patients aged 18 years or over. The remaining patients were considered for evaluation if they satisfied the following selection criteria.

Inclusion criteria:

- orthodontic treatment with the Invisalign® appliance only;
- no orthodontic extractions;
- completion of wear of the initial series of aligners;
- compliance with prescribed aligner wear protocols as determined by the treating orthodontist;
- CAT where additional aligners can no longer be ordered from Align–5 years after acceptance of the initial DTP. Thus, cases were selected which had commenced treatment in 2017 and 2018 to provide the most recent complete data;
- availability of the first refinement scan to capture the OJ and OB data after the initial series of aligners.

Exclusion criteria:

- patients undergoing combined CAT/orthognathic surgery;
- patients with cleft palate or other syndromes;
- patients with hypodontia or supernumerary teeth;
- patients treated with the Invisalign® mandibular advancement appliance or with "Invisalign First", a mixed dentition treatment appliance.

The patients satisfying selection criteria were chosen on a consecutive basis according to having most 'recently commenced treatment' to less recently. Each included patient was allocated a number which was documented on an Excel® (Microsoft, Washington, DC, USA) spreadsheet. Up to a maximum number of 40 patients per orthodontist was chosen. The patient numbers were then entered into a random sequence of integer generator (<https://www.random.org/sequences/>) to randomly select 300 patients which corresponded to that evaluated in CAT investigations [4,9,16].

The following information from patients selected for evaluation was taken from the ClinCheck® software facility and documented on an additional Excel spreadsheet:

- patient sex and age;
- the number of initial DTPs prior to acceptance of the initial DTP by the orthodontist;
- the number of additional (refinement) DTPs before acceptance of the refinement DTP by the orthodontist;
- the number of additional (refinement) plans per patient;
- the number of aligners prescribed per patient from the initial DTP;
- the number of aligners prescribed per patient from the refinement plans;

- the pre-treatment and planned OJ and OB values from the initial DTP;
- the 'pre-treatment' OJ and OB values from the first refinement scan which is, in effect, the achieved outcome from the initial DTP's series of aligners.

Although the process by which the ClinCheck® facility obtains OJ and OB measurement values is unknown, a recent study has validated the OJ and OB changes recorded by the ClinCheck® facility [17].

Statistical analysis

Statistical analyses were carried out using GraphPad Prism 9.0 (GraphPad Software Inc., La Jolla, CA, USA). The Shapiro-Wilks test determined that the distribution of data was non-parametric. Descriptive statistics were presented in medians,

interquartile ranges (IQR) and percentages. Statistical analysis included stratification of OJ and OB into the following categories: < 2 mm, 2–4 mm, > 4 mm.

The Mann Whitney and the Wilcoxon rank-sum tests were used to assess significant differences between the groups evaluated. Fifty patients were randomly chosen 4 weeks after data analysis to determine intra-rater reliability in data entry to the Excel® spreadsheet with intra-correlation coefficient (ICC) testing.

Results

Figure 1 indicates that just 3.33% ($n = 10$) of the 300 patients that otherwise satisfied inclusion and exclusion criteria did not require a refinement scan and were excluded from further analysis.

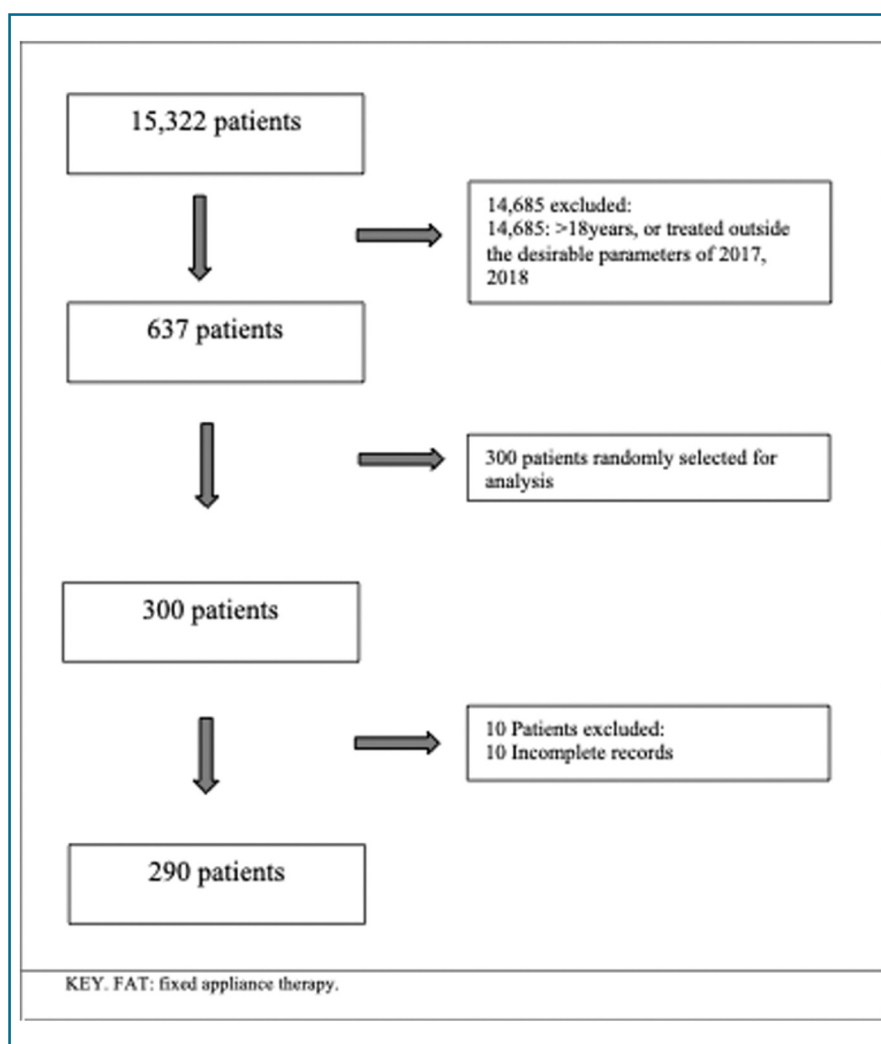


FIGURE 1

Flow diagram showing patient selection

Table I shows there was almost twice as many females as males evaluated. A Mann Whitney test signified that there was no difference ($p = 0.06$) in the median (IQR) ages of the males [14.42 (13.42, 15.63)] and females [14.14 (12.75, 15.35)]. The total number of aligners prescribed per dental arch was 1,7388. *Table II* outlines the pre-treatment, planned, and achieved OJ measurements for patients where a change, or no

change, in OJ was prescribed as part of the DTP and shows that 53.33% of the planned median OJ increase achieved and 52.94% of planned median OJ reduction achieved. Overall, less than 60% of the planned OJ changes were achieved.

Table III outlines the measurements according to the pre-treatment OJ measurement value.

TABLE I
Demographic statistics ($n = 290$)

		<i>n</i> (%)		
Sex	F	187 (64.49)		
	M	103 (35.51)		
		Median	IQR	Min, Max
Age	Total	14.17	13, 15.42	10.42, 17.67
	F	14.04	12.75, 15.35	10.42, 17.67
	M	14.42	13.42, 15.63	11.33, 17.5
Initial DTPs before acceptance by orthodontist		2	2, 3	1, 13
Aligners per initial accepted DTP per patient		29	23, 40	8, 96
RDTPs before acceptance by orthodontist		3	2, 4	0, 13
RDTP per patient		1	1, 2	0, 5
Aligners per initial RDTP		17	12, 25	0, 96
Aligners per overall refinement phase		24	14, 36	0, 152
Aligners per patient		53	41, 73.25	17, 208

n: number; F: female; M: male; IQR: interquartile range; Min: minimum; Max: maximum; DTP: digital treatment plan; RDTP: refinement digital treatment plan.

TABLE II
Pre-tx, planned and achieved OJ measurements ($n = 290$)

		Pre-tx	Planned	Achieved	% change of planned change achieved	<i>p</i>
Planned OJ ↑ $n = 48$	Median	1.6	2.35	2.0	53.33	0.0012
	IQR	1.15, 1.6	1.83, 3.1	1.43, 2.58		
	Min, Max	-2, 5.1	1.1, 6.7	0.1, 8.3		
Planned OJ ↓ $n = 237$	Median	3.6	1.9	2.7	52.94	< 0.0001*
	IQR	2.8, 4.8	1.5, 2.35	1.9, 3.7		
	Min, Max	1.0, 10.1	0.1, 4.8	0.8, 9.5		
No planned OJ ↑↓ $n = 5$	Median	2.2	2.2	3.0	-	0.625
	IQR	1.65, 3.25	1.65, 3.25	1.2, 5.6		
	Min, Max	1.3, 3.7	1.3, 3.7	0.2, 7.4		

Pre-tx: pre-treatment; OJ: overjet; *n*: number; P: Wilcoxon rank-sum test; * $p < 0.05$ statistically significant; ↑: increase; IQR: interquartile range; Min: minimum; Max: maximum; ↓: decrease; No ↑↓: no change.

TABLE III

Pre-tx, planned and achieved OJ measurements categorized by pre-tx measurements ($n = 285$)

	Pre-tx OJ	N	Pre-tx	Planned	Achieved	% change of planned change achieved	p
Planned OJ ↑ $n = 48$	< 2 mm	30	1.35 (1, 1.6)	2.1 (1.6, 2.48)	1.7 (1.35, 2.15)	46.67	0.0464*
	2–4 mm	15	2.6 (2, 3)	3.1 (2.8, 3.9)	2.5 (2, 3.3)	–20	0.0054*
	> 4 mm	3	4.6 (4.4, 5.1)	5.6 (4.5, 6.7)	4.6 (2, 7)	0	0.5
Planned OJ ↓ $n = 237$	< 2 mm	16	1.65 (1.6, 1.98)	1.3 (1.1, 1.55)	1.3 (1.03, 1.83)	100	0.71
	2–4 mm	126	3.1 (2.7, 3.6)	1.9 (1.5, 2.3)	2.4 (1.9, 3.1)	58.33	< 0.0001*
	> 4 mm	95	5.1 (4.6, 6.4)	1.9 (1.5, 2.6)	3.6 (2.6, 4.8)	46.87	< 0.0001*

Pre-tx: pre-treatment; OJ: overjet; n : number; IQR: interquartile range; P : Wilcoxon rank-sum test; * $p < 0.05$ statistically significant; ↑: increase; < less than; > greater than; ↓: decrease.

A total of 51/237 (21.51%) patients recorded no change or an increase from the initial to the achieved OJ where a decrease was planned, whereas 20/48 (41.67%) patients recorded no change or a decrease in OJ where an increase in OJ was planned. Table IV summarizes the pre-treatment, planned, and achieved OB measurements for patients where a change in OB was prescribed as part of the DTP and shows that 58.33% of the planned median OB increase was achieved and 55.55% of the planned median OB reduction was achieved.

Table V shows 50% of the planned OB reduction in patients with a pre-treatment OB > 4 mm was achieved and 56.67% of the planned overbite reduction was achieved in patients with a pre-treatment OB of 2 to 4 mm.

A total of 44/235 (18.72%) patients recorded no change or an increase in OB where a decrease in OB was planned, whereas 11/53 (20.75%) patients recorded no change or a decrease in OB where an increase in OB was planned.

TABLE IV

Pre-tx, planned and achieved OB measurements ($n = 290$)

		Pre-tx	Planned	Achieved	% change of planned change achieved	p
Planned OB ↑ $n = 53$	Median	0.5	1.7	1.2	58.33	0.0005*
	IQR	–0.45, 1.1	1.2, 2.15	0.55, 2.8		
	Min, Max	–5.4, 2.5	–0.6, 3.2	–4.5, 2.8		
Planned OB ↓ $n = 235$	Median	4.1	1.4	2.6	55.55	< 0.0001*
	IQR	3.0, 5.0	0.7, 1.8	1.83.5		
	Min, Max	0, 10.3	–1.8, 3.3	–1, 7.3		
No planned OB ↑↓ $n = 2$	Median	1.9	1.9	1.7	–	–
	IQR	1.5, 2.3	1.5, 2.3	1.3, 2.1		
	Min, Max	1.5, 2.3	1.5, 2.3	1.3, 2.1		

Pre-tx: pre-treatment. OB: overbite. n : number. P : Wilcoxon rank-sum test; * $p < 0.05$ statistically significant. ↑: increase. IQR: interquartile range. Min: minimum. Max: maximum. ↓: decrease. No ↑↓: no change.

TABLE V

Pre-tx, planned and achieved OB measurements categorized by pre-tx measurements ($n = 285$)

	Pre-tx OB	<i>n</i>	Median (IQR)				
			Pre-tx	Planned	Achieved	% change of planned change achieved	
Planned OB ↑ <i>n</i> = 53	< 2 mm	52	0.45 (−0.48, 1.08)	1.6 (1.2, 2.1)	1.2 (0.53, 1.9)	65.21	0.0008
	2–4 mm	1	2.5	2.8	2.4	–	–
	> 4 mm	0	–	–	–	–	–
Planned OB ↓ <i>n</i> = 235	< 2 mm	18	1.7 (1.1, 1.8)	1.15 (0.08, 1.4)	1.7 (0.95, 3.1)	0	0.0008
	2–4 mm	92	3.1 (2.53, 3.6)	1.6 (1.1, 1.9)	2.25 (1.7, 3.1)	56.67	< 0.0001
	> 4 mm	125	4.9 (4.5, 5.45)	1.3 (0.4, 1.9)	3.1 (2.25, 4)	50	< 0.0001

Pre-tx: pre-treatment; OB: overbite; N: number; IQR: interquartile range; P: Wilcoxon rank-sum test; * $p < 0.05$ statistically significant; †: increase; < less than; > greater than; ↓: decrease.

The ICC scores for data inputting from the ClinCheck® facility to the Excel spreadsheets scored very highly (0.97 to 1).

Discussion

The present study aimed to evaluate the achieved changes in OJ and OB measurements provided by the ClinCheck® facility in the first refinement DTP accepted by the orthodontist and compare it with the changes planned in the initial accepted DTP. The objective was to determine how closely the measurements planned by the orthodontist at the outset matched the measurements at the end of the initial series of aligners, not to assess how successful the orthodontist was in achieving objectively ideal occlusal outcomes [18]. The findings of the present investigation indicated that the OJ and OB changes at the end of the initial sequence of aligners did not match the planned changes recorded in the initial DTP in most patients. The null hypothesis was rejected.

The present study appears to be among the first to focus on and compare the OJ and OB changes achieved in adolescent patients with the Invisalign® appliance with those planned by orthodontists via its ClinCheck® DTP facility. A total of 300 patients were initially screened which corresponded to the sample sizes investigated in similar studies.

Studies assessing CAT in adolescent patients only appear to be lacking and limited to the use of the Invisalign®'s 'Class II functional appliance', the Mandibular Advancement Appliance (MAA) in the main, although several investigations have included patients less than 18-years of age in addition to adults in their samples [4,8,9,12,19–26]. Caution, therefore, is required in the comparison of the present investigation with the available literature.

This study assessed 290 patients which compared with 1 to 195 in studies that investigated CAT with the MAA [19,20,22–25]. Males comprised 35.1% of the patients evaluated and this

compared with a range of 45.58 to 60.31% of males who were evaluated in similar studies among adolescent patients and was greater than the maximum of 30% reported in studies among adult patients [4,9,10,20–24]. This may have reflected the different motivations and attitudes towards orthodontic treatment between adults and children [27].

The median age of the patients at pre-treatment evaluation in the present study was 14.17 years. This compared with the mean age of 9.2 to 13.6 years in studies investigating the efficacy of Invisalign®'s MAA [20,21,23–25]. The higher median age recorded in the present study may have reflected a CAT patient demographic analogous to the adolescent cohort who undertake comprehensive fixed appliance therapy.

A median of two initial DTPs were required per patient before acceptance of the DTP by the orthodontist. This compared with three in a recent retrospective study among 324 adult and adolescent patients and with the required one-to-three DTPs reported by orthodontists in recent surveys [2–4].

The study found that a median of one refinement plan per patient was required which was comparable to a mean of 0.79 to 2.5 plans in studies appearing to include patients less than 18-years of age in addition to adult patients [4,8,9,28,29]. An initial series of a median of 29 aligners per patient in the present study corresponded with 24 to 28 aligners in recent studies among adult patients and 23.1 to 44.7 in retrospective studies which included adult and adolescent patients [4,11,28,29]. The median total number of aligners per patient (53) compared with a mean of approximately 65 in two investigations [8,28].

Less than 60% of the planned OJ changes were achieved in the initial DTP and this compared with 40% where a decrease in OJ was planned and 66.67% where an increase in OJ was planned in a similar study among adult patients [11]. Additionally, the achieved OB reduction of a median of 1.8 mm in patients with a

pre-treatment OB greater than 4 mm contrasted with a median of 1.5 mm reduction in a cephalometric study including adult patients with the same pre-treatment OB [30]. However, the 1.8 mm reduction was only 50% of that planned which corresponded with approximately 40% to 45% recorded in studies elsewhere [5,11,31].

The findings from several studies, using different methodologies, have indicated that the achieved movements for individual teeth and groups of teeth can vary widely from that planned in the initial DTP [5-7,30,31]. The present survey, for example, showed.

Among the patients, 21.52% recorded no change or an increase from the initial to the achieved OJ where a decrease was planned, whereas 41.67% of patients recorded no change or a decrease in OJ where an increase in OJ was planned. In addition, a total of 18.72% patients recorded no change or an increase in OB where a decrease in OB was planned and 20.75% of patients recorded no change or a decrease in OB where an increase in OB was planned. The changes in OJ and OB measurements that were in the 'opposite direction', or no different to the pre-treatment measurements, to that planned in the initial DTP are likely to be clinically significant and suggested that the cumulative effects of deviation from planned tooth movements may have contributed to the variability in the planned OJ and OB outcomes. Additionally, in the cohort evaluated in the present study, the effects of growth are likely to impact on outcomes. Further research is required to investigate the role of biological, appliance material, technological and patient compliance factors in the wide variance of outcomes observed in this investigation [4,13].

The present study was retrospective. As such, it was at high risk of selection bias. The risk was minimised by the random selection of patients from many orthodontists experienced in the use of Invisalign® and the adherence to strict inclusion and exclusion criteria. Furthermore, an age of 18-years was chosen as an arbitrary cut-off point for adolescent patients. This is a common age to delineate growing and non-growing patients in studies, but the present investigation may have included patients who have already ceased growth by that timepoint. Furthermore, the number of patients prescribed OJ reduction and OB reduction exceeded those prescribed an increase in the variables but is likely representative of what orthodontists encounter in practice.

A strength of the investigation was the inclusion only of patients for whom additional aligners could no longer be ordered without an extra patient cost being paid. This enabled a comprehensive evaluation of initial and refinement DTPs and aligner provision to patients [4]. In addition, the study aimed to investigate a large number of patients treated by 17 experienced orthodontists in the use of Invisalign®, adopting the bio-mechanical strategies routinely used in the management of their patients prescribed with the appliance.

The findings of this investigation contribute new data regarding the planned and achieved OJ and OB changes with the Invisalign® appliance in adolescent patients. By quantifying the percentage difference between the DTP and the achieved change, the orthodontist may be better placed to assess the magnitude of overcorrection or the requirement for ongoing refinement to achieve the planned clinical outcome. In the absence of comprehensive studies investigating CAT in this cohort, it provides baseline data for future prospective research and information that can be shared regarding CAT in valid consent processes [32].

Conclusions

From the cohort of adolescent patients assessed in this investigation, it can be concluded that:

- the median number of initial DTPs and additional aligner/refinement plans before acceptance by the orthodontist was 2 and 3 respectively;
- the median number of aligners prescribed per patient was 53 with 54.71% prescribed in the initial DTP and 45.29% prescribed in the additional aligner/refinement phase;
- achieved OJ and OB measurements at the end of an initial sequence of aligners did not match the measurements planned in the initial DTP with less than 60% of the planned outcomes being achieved;
- just over half of planned OJ changes were achieved with 53.33% of the planned median OJ increase and 52.94% of planned median OJ reduction achieved at completion of wear of the initial series of aligners;
- less than 60% of planned OB changes were achieved with 58.33% of the planned median OB increase and 55.55% of the planned median OB reduction achieved;
- between 22.51% and 41.67% of patients experienced no change or changes in their OJ outcomes opposite to what was planned;
- between 18.72 and 20.75% of patients experienced no change or changes in their OB outcomes opposite to what was planned.

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Contribution: MJM: concept and design of the work; analysis and interpretation of data; drafting and revision of the article; critical review of the important intellectual content.

TW: concept and design of the work; acquisition, analysis and interpretation of data; drafting and revision of the article; critical review of the important intellectual content.

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References

- [1] Lynch NM, Shroff B, Carrico CK, Sawicki V, Sabol M, Lindauer SJ. Clear aligner therapy in the mixed dentition: indications and practitioner perspectives. *Am J Orthod Dentofacial Orthop* 2023;164:172–82.
- [2] Meade MJ, Weir T. A survey of orthodontic clear aligner practices among orthodontists. *Am J Orthod Dentofacial Orthop* 2022;162:e302–11.
- [3] Meade MJ, Weir T, Seehra J, Fleming PS. Clear aligner therapy practice among orthodontists in the United Kingdom and the Republic of Ireland: a cross-sectional survey of the British Orthodontic Society membership. *J Orthod* 2023;13. doi: [10.1177/14653125231204889](https://doi.org/10.1177/14653125231204889). 14653125231204889. Epub ahead of print. PMID: 37830274.
- [4] Meade MJ, Ng E, Weir T. Digital treatment planning and clear aligner therapy: a retrospective cohort study. *J Orthod* 2023;50:361–6.
- [5] Bowman E, Bowman P, Weir T, Dreyer CW, Meade MJ. Evaluation of the predicted vs. achieved occlusal outcomes with the Invisalign® appliance: a retrospective investigation of adult patients. *Int Orthod* 2023;21:100746.
- [6] Goh S, Dreyer C, Weir T. The predictability of the mandibular curve of Spee leveling with the Invisalign appliance. *Am J Orthod Dentofacial Orthop* 2022;162:193–200.
- [7] Stephens C, Weir T, Llewellyn S, Freer E, Kerr B. Clinical expression of programmed mandibular canine rotation using various attachment protocols and 1- vs 2-week wear protocols with Invisalign SmartTrack aligners: a retrospective cohort study. *Am J Orthod Dentofacial Orthop* 2022;162:e103–15.
- [8] Kravitz ND, Dalloul B, Zaid YA, Shah C, Vaid NR. What percentage of patients switch from Invisalign to braces? A retrospective study evaluating the conversion rate, number of refinement scans, and length of treatment. *Am J Orthod Dentofacial Orthop* 2023;163:526–30.
- [9] Arqub SA, Banankhah S, Sharma R, Godoy LD, Kuo CL, Ahmed M, et al. Association between initial complexity, frequency of refinements, treatment duration, and outcome in Invisalign orthodontic treatment. *Am J Orthod Dentofacial Orthop* 2022;162:e141–55.
- [10] Charalampakis O, Iliadi A, Ueno H, Oliver DR, Kim KB. Accuracy of clear aligners: a retrospective study of patients who needed refinement. *Am J Orthod Dentofacial Orthop* 2018;154:47–54.
- [11] Meade MJ, Weir T. Predicted and achieved overjet and overbite measurements with the Invisalign® appliance: a retrospective study. *Angle Orthod* 2024;94:3–9.
- [12] Kravitz ND, Hansa I, Vaid NR, Moshiri M, Adel SM. Does age influence deep overbite correction with Invisalign? A prospective study evaluating mandibular incisor intrusion in adolescents vs adults. *Angle Orthod* 2024;94:145–50.
- [13] Timm LH, Farrag G, Baxmann M, Schwen-dicke F. Factors influencing patient compliance during clear aligner therapy: a retrospective cohort study. *J Clin Med* 2021;10:3103.
- [14] Boyd RL, Miller R, Vaskalic V. The Invisalign system in adult orthodontics: mild crowding and space closure cases. *J Clin Orthod* 2000;34:203–12.
- [15] Alwafi A, Bichu YM, Avanesian A, Adel SM, Vaid NR, Zou B. Overview of systematic reviews and meta-analyses assessing the predictability and clinical effectiveness of clear aligner therapy. *Dent Rev* 2023;3(4):100074.
- [16] Abasseri T, Weir T, Meade MJ. Interproximal reduction in the refinement phase of Invisalign treatment: a quantitative analysis. *Am J Orthod Dentofacial Orthop* 2024. doi: [10.1016/j.ajodo.2024.02.005](https://doi.org/10.1016/j.ajodo.2024.02.005). S0889-5406(24)00063-5 Epub ahead of print.
- [17] Meade MJ, Blundell H, Weir T. Predicted overbite and overjet changes with the Invisalign appliance: a validation study. *Angle Orthod* 2024;94:10–6.
- [18] Andrews LF. The six keys to normal occlusion. *Am J Orthod* 1972;62:296–309.
- [19] Sabouni W, Hansa I, Al Ali SM, Adel SM, Vaid N. Invisalign treatment with mandibular advancement: a retrospective cohort cephalometric appraisal. *J Clin Imaging Sci* 2022;12:42.
- [20] Wu Y, Yu Q, Xia Y, Wang B, Chen S, Gu K, et al. Does mandibular advancement with clear aligners have the same skeletal and dentoalveolar effects as traditional functional appliances? *BMC Oral Health* 2023;23:65.
- [21] Ravera S, Castorflorio T, Galati F, Cugliari G, Garino F, Deregibus A, et al. Short term dentoalveolar effects of mandibular advancement clear aligners in Class II growing patients. A prospective controlled study according to STROBE Guidelines. *Eur J Paediatr Dent* 2021;22:119–24.
- [22] Sun R, Liu P. Treatment of an adolescent patient with Class II Division 2 malocclusion with mandibular retrognathism and excessive overbite using Invisalign aligners. *AJO-DO CC* 2022;2:572–88.
- [23] Zybutz T, Drummond R, Lekic M, Brownlee M. Investigation and comparison of patient experiences with removable functional appliances: Invisalign teen with mandibular advancement versus twin block. *Angle Orthod* 2021;91:490–5.
- [24] Lombardo EC, Lione R, Franchi L, Gaffuri F, Maspero C, Cozza P, et al. Dentoalveolar effects of clear aligner vs twin block—a short-term study of functional appliances. *J Orofac Orthop* 2023;18:1–9.
- [25] Meade MJ, Weir T. Clinical efficacy of the Invisalign mandibular advancement appliance: a retrospective investigation. *Am J Orthod Dentofacial Orthop* 2024;165:503–12.
- [26] Hosseini HR, Ngan P, Tai SK, Andrews II LJ, Xiang J. A comparison of skeletal and dental changes in patients with a Class II relationship treated with clear aligner mandibular advancement and Herbst appliance followed by comprehensive orthodontic treatment. *Am J Orthod Dentofacial Orthop* 2024;165:205–19.
- [27] Pabari S, Moles DR, Cunningham SJ. Assessment of motivation and psychological characteristics of adult orthodontic patients. *Am J Orthod Dentofacial Orthop* 2011;140:e263–72.
- [28] Hansa I, Semaan SJ, Vaid NR. Clinical outcomes and patient perspectives of Dental Monitoring® GoLive® with Invisalign®—a retrospective cohort study. *Prog Orthod* 2020;21:1–7.
- [29] Hansa I, Katyal V, Ferguson DJ, Vaid N. Outcomes of clear aligner treatment with and without dental monitoring: a retrospective cohort study. *Am J Orthod Dentofacial Orthop* 2021;159:453–9.
- [30] Khosravi R, Cohanin B, Hujoel P, Daher S, Neal M, Liu W, et al. Management of overbite with the Invisalign appliance. *Am J Orthod Dentofacial Orthop* 2017;151:691–9.
- [31] Blundell HL, Weir T, Kerr B, Freer E. Predictability of overbite control with the Invisalign appliance. *Am J Orthod Dentofacial Orthop* 2021;160:725–31.
- [32] Meade MJ, Weston A, Dreyer CW. Valid consent and orthodontic treatment. *Aust Orthod J* 2019;35:35–45.