Occlusal Contact Outcomes with Invisalign® Lite Treatment

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Objective: To investigate the relationship between pre-treatment, predicted post-treatment, and clinically achieved numbers and locations of occlusal contact in cases treated using the Invisalign® Lite appliance (Align Technology, San Jose, California, USA).

Materials and Methods: Following the application of exclusion and inclusion criteria, 34 patients treated with the Invisalign® Lite appliance were selected. Occlusal contacts were measured at the initial, predicted, and achieved stages on amiga disc file (.adf file) files using the imaging software ImageJ (National Institutes of Health, Bethesda, MD, USA). Descriptive statistics were calculated. Predicted values were provided by Align Technology’s treatment planning software interface, ClinCheck®.

Results: Most patients were female (n = 29; 85.3%) and the mean (standard deviation) age of the sample was 33.4 (10.72) years. There were significant differences between the initial pre-treatment number of maxillary premolar and molar occlusal contacts and the achieved (a reduction of 58.97%; P < 0.0001), and the total initial pre-treatment number of premolar and molar occlusal mandibular contacts and the achieved (a reduction of 52.5%; P < 0.0001). A significant reduction in the number of posterior occlusal contacts was observed when the achieved number of posterior occlusal contacts was compared to the numbers predicted via ClinCheck® (p<0.0001).

Conclusions: For minor tooth movement treatment with Invisalign® Lite, more than 50% loss of posterior contact was observed in the achieved outcome when compared to either the initial or predicted number of occlusal contacts.

Introduction

The introduction of Invisalign® (Align Technology, San Jose, California, USA) in 1998 marked the beginning of modern clear aligner therapy (CAT). The provision of CAT has become increasingly popular, particularly for the treatment of mild malocclusions. Align Technology provides a system called Invisalign® Lite which is intended to address minor crowding and/or spacing within a maximum of 14 aligners.

Enabling the required tooth movements to be prescribed, most CAT manufacturers use digital treatment planning software to communicate between the treating doctor and the manufacturer. A sequence of aligners is then produced to deliver an intended occlusal outcome. Studies show that one or more refinement phases, involving the prescription of additional aligners, are frequently necessary to achieve the desired occlusal outcome. ClinCheck® is the proprietary digital treatment planning software interface used by Align Technology for its Invisalign® appliances.

A routine objective of orthodontic treatment is to achieve on mouth closure, an even, simultaneous, and symmetrical contact of all anterior and posterior teeth with the intention of aiding in the provision of optimal stability within the masticatory system.

Several studies, however, have reported poor posterior occlusal contact outcomes as a potential complication of CAT. A 2020 meta-analysis...
reported a mean deficiency of 4.45 points (95% CI: 2.72-6.18 points, \( p < 0.001 \)) in occlusal contact outcomes using the American Board of Orthodontics Objective Grading Scoring (ABOOGS) tool in cases treated with the Invisalign® appliance compared with fixed appliances.\(^{16,17}\) Recently, Bowman et al. retrospectively evaluated the accuracy of the ClinCheck® predictions of occlusal contact compared to the achieved outcomes using metrology to analyse occlusal contact.\(^{18}\) A decrease in the number of posterior occlusal contacts was reported compared to the digitally prescribed outcome and the pre-treatment situation in mild-to-moderate cases.

The cause of posterior contact loss with CAT remains unclear. Proposed aetiologies include the interposition of aligner material between the posterior teeth causing a bite-block effect, and failure to completely achieve prescribed movements such as bite opening, torque, or posterior dental expansion.\(^{15,19,20}\)

Relevant research involving the Invisalign® appliance, however, has only evaluated changes predicted and observed following comprehensive Invisalign® treatment. The aims of the present study, therefore, were to investigate the relationship between pre-treatment, predicted post-treatment, and clinically achieved occlusal contact numbers and locations around the dental arches in cases treated using the Invisalign® appliance by 16 experienced orthodontists in Australia, New Zealand and the USA. AARD currently holds the complete Invisalign® treatment records of approximately 16,000 cases.

Patients were chosen for evaluation if they satisfied the following inclusion criteria:

1. Dual arch non-extraction orthodontic treatment exclusively with the Invisalign® Lite appliance between 2017 and 2021
2. A complete permanent dentition excluding third molars
3. \( \geq 18 \) years old
4. Completion of the entire initial prescribed sequence of aligners
5. ClinCheck® [.amiga disc file (.adf file)] digital models which had complete capture of the anatomy of the permanent dentition excluding the third molars at the initial and achieved timepoints.
6. Requiring an additional ‘refinement’ series of aligners to enable analysis on an .adf file corresponding to the end of the series of 14 aligners of the Invisalign® Lite appliance.

Patients who were taking medication that may have inhibited tooth movement, such as bisphosphonates, were excluded from the study.

Pre-treatment and end of initial aligner sequence (achieved) digital models (.adf files) were obtained from ClinCheck®. Occlusal screenshots of the ClinCheck® models, with occlusal contacts shown were exported to imaging analysis software (ImageJ, National Institutes of Health, Bethesda, MD, USA) (Figures 1, 2). The green occlusal contacts in the image were converted to red for ease of definition in ImageJ, and then to greyscale for analysis (Figure 2). Minimum and maximum pixel thresholds were defined, and the rectangle select tool was employed.

**Materials and methods**

Institutional ethical approval was obtained from University of Adelaide Human Research Ethics Committee (H-2022-197).

The sample for the investigation was obtained from the Australasian Aligner Research Database (AARD), which is a database comprised of all patients treated

![Figure 1. Images of occlusal contacts (green) as displayed in ClinCheck® for the initial (A), predicted finish (B) and outcome as start of additional aligner order (C) stages of treatment.](image-url)
to analyse the desired area on the image. Data were recorded and a manual count was performed by zooming the image to 750% magnification to allow for separate occlusal contacts to be noted if a continuous border (minimum 1 pixel thickness) of non-green pixels separated a collection of green pixels from adjacent green pixels.

The number of occlusal contacts per tooth per arch was recorded in Microsoft Excel (Microsoft Corp., DC, USA) spreadsheet. The data were grouped according to molar (first permanent molars and second permanent molars), premolar (first premolars and second premolars) and anterior (permanent canines and permanent incisors). The mean number of contacts per group comprised the assessed data.

**Statistics**

Descriptive and inferential statistics were calculated via GraphPad Prism® (GraphPad Software Inc., La Jolla, California, United States). The Shapiro–Wilks test was used to determine the normality of the assessed groups and sub-groups.

As the groups and sub-groups had a non-normal distribution, the Mann–Whitney and Wilcoxon rank-sum tests were used to ascertain significant differences. The relevant data of eight randomly chosen patients were assessed via intra-correlation coefficient (ICC) testing to evaluate intra- and inter-rater reliability one month after the initial assessment.

**Results**

Figure 3 shows that 34 (29 female; 5 male) patients satisfied the inclusion and exclusion criteria. The mean [standard deviation (SD)] age of the sample was 33.4 (10.72) years. The Mann-Whitney test indicated that there was no difference between the mean (SD) age of females [33.3 (10.01)] and males [34.02 (15.71), \( p = 0.79 \)].

Tables I and II show that there were significant reductions in the number of occlusal contacts between the predicted and achieved outcome for premolars (maxilla: 66.67%; mandible: 62.5%) and molars (maxilla: 62.06%; mandible: 56.67%).

Figure 4 illustrates that the achieved total number of maxillary occlusal contacts was significantly less than predicted.

There was no difference between the initial presenting and predicted total number of maxillary occlusal contacts (\( p = 0.90 \)) and the initial presenting and predicted total number of mandibular occlusal contacts (\( p = 0.99 \)). However, there were significant differences between the initial pre-treatment number of maxillary premolar and molar occlusal contacts and the achieved (a reduction of 58.97%; \( P < 0.0001 \)), and the total initial pre-treatment number of premolar and molar occlusal mandibular contacts and the achieved (a reduction of 52.5%; \( P < 0.0001 \)).

ICC scores were high with an intra-rater range of between 0.96 to 1.0 and an inter-rater range of 0.94 to 0.96.
Discussion

The present study appears to be the first to investigate the relationship between the pre-treatment, predicted and achieved outcomes regarding the number of occlusal contacts related to the Invisalign® Lite appliance. The findings suggested that the number of posterior occlusal contacts was significantly less than that present in the patients prior to commencing treatment and significantly less than that predicted by the treatment planning software interface.

The screening process revealed that the Invisalign® Lite appliance was infrequently prescribed by the orthodontists involved in the AARD database and that most patients treated using the appliance required a refinement phase. This was similar to studies investigating treatment outcomes associated with the Invisalign® appliance and suggested that mild crowding and spacing may not be easily addressed by a relatively small number of aligners.\textsuperscript{19,21}

The mean age of the subjects evaluated in the present study was 33.4 years. This was similar to the mean age observed in corresponding investigations and is representative of the age when patients commonly undertake CAT.\textsuperscript{16,21–23} The present investigation comprised cases requiring only minor tooth movements and were limited to treatment consisting of a series of 14 aligners. This aimed to minimise the influence of variables including intermaxillary elastic wear, extraction space closure or difficult tooth movements which may risk non-tracking and, therefore, further influence the number of occlusal contacts achieved at the end of treatment. The methodology adopted, utilising the imaging analysis software ImageJ, was similar to that used in other studies investigating occlusal contact and the inter- and intra-rater scores showed a high level of consistency in the evaluation.\textsuperscript{14,25}

The findings of this investigation corresponded with several studies that have shown that the achieved clinical outcome of CAT falls short of the outcome predicted in the digital treatment plan.\textsuperscript{15,20,21,26,27} The present study showed that, even in the absence of major tooth movements, CAT using the Invisalign® Lite appliance resulted in a greater than 50% reduction in tooth contacts of posterior teeth from the initial presenting occlusion to the achieved occlusion at the end of the initial sequence of aligners. Furthermore, the percentage reduction

<table>
<thead>
<tr>
<th>Tooth type</th>
<th>I</th>
<th>P</th>
<th>A</th>
<th>P vs A#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molars</td>
<td>13 (8, 20)</td>
<td>14.5 (11, 17.5)</td>
<td>5.5 (2, 11.25)</td>
<td>P &lt; 0.0001*</td>
</tr>
<tr>
<td>Premolars</td>
<td>6.5 (4, 9.25)</td>
<td>7.5 (6, 10)</td>
<td>2.5 (1, 6)</td>
<td>P &lt; 0.0001*</td>
</tr>
<tr>
<td>Anterior</td>
<td>5.5 (2, 7.25)</td>
<td>3 (1, 5)</td>
<td>3.5 (1, 6)</td>
<td>P = 0.7</td>
</tr>
<tr>
<td>Total</td>
<td>26 (16, 35.5)</td>
<td>27 (19.75, 30)</td>
<td>14.5 (7.75, 180)</td>
<td>P &lt; 0.0001*</td>
</tr>
</tbody>
</table>

# Wilcoxon rank-sum test.
* Statistically significant.
A, achieved; I, initial; IQR, interquartile range; n, number; P, predicted.

Table II. Median (IQR) number of initial, predicted and achieved mandibular occlusal contacts according to tooth type per patient (n = 34).

<table>
<thead>
<tr>
<th>Tooth type</th>
<th>I</th>
<th>P</th>
<th>A</th>
<th>P vs A#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molar</td>
<td>13 (9.75, 19.25)</td>
<td>15 (12.75, 18.25)</td>
<td>6.5 (2, 10.5)</td>
<td>P &lt; 0.0001*</td>
</tr>
<tr>
<td>Premolar</td>
<td>7 (3.75, 10)</td>
<td>8 (6.75, 9.25)</td>
<td>3 (1, 5.25)</td>
<td>P &lt; 0.0001*</td>
</tr>
<tr>
<td>Anterior</td>
<td>5 (2, 7)</td>
<td>2 (1, 5)</td>
<td>3 (1, 5)</td>
<td>P = 0.07</td>
</tr>
<tr>
<td>Total</td>
<td>24.5 (18.75, 33)</td>
<td>27 (19.75, 31.25)</td>
<td>15 (8, 18)</td>
<td>P &lt; 0.0001*</td>
</tr>
</tbody>
</table>

# Wilcoxon rank-sum test.
* Statistically significant.
A, achieved; I, initial; IQR, interquartile range; n, number; P, predicted.
was significantly greater when the achieved number of posterior occlusal contacts was compared to the number predicted via ClinCheck®. Of note, however, were the minimal differences in the corresponding comparisons regarding the anterior teeth. These findings reflected the outcomes from similar recent studies which use metrology software, of adult patients presenting with a mild-to-moderate Class I malocclusion and treated using the Invisalign® appliance. A future investigation is required to determine the treatment planning, aligner material and patient factors that result in a worsening of the number of posterior occlusal associated with CAT appliances.

The current investigation evaluated the number and location of occlusal contacts at the end of the initial series of aligners only. The effect of additional prescribed ‘refinement’ aligners, on the number and location of occlusal contacts was not evaluated. It may be reasonable to consider, however, that the reported reasons for sub-optimal occlusal contact with CAT, such as the presence of the aligner material precluding occlusal contact and the failure to completely achieve prescribed tooth movements may result in greater loss of posterior occlusal contact.

Optimal occlusal contact is considered an essential treatment goal as it can reduce the stresses imparted to the teeth during function, facilitate maximal masticatory efficiency and potentially enhance post-orthodontic treatment stability. Even though settling of the occlusion post-CAT may result in an increase in the number of occlusal contacts, investigations have concluded that these contacts are sub-optimal and fail to reach the pre-treatment number of contacts. Furthermore, the findings of a recent survey have indicated that up to 90% of patients are prescribed a thermoplastic retainer after CAT as part of their retention strategy which suggests that most patients still potentially face the issue of the thickness of the retainer material preventing favourable settling. Consequently, optimal occlusion should ideally be achieved by the end of active treatment.

The limitations of the study must be acknowledged. The investigation was retrospective and therefore subject to bias. However, strict inclusion and exclusion criteria were applied to a large database to minimise this. In addition, a qualitative assessment of the area of the occlusal contacts was not undertaken. Future research should incorporate a qualitative evaluation of the change in occlusal contacts with this and other CAT appliances and the resulting clinical implications. Furthermore, the findings of this study are applicable only to non-growing patients undergoing orthodontic treatment using the Invisalign® Lite appliance.

Conclusions

- This appears to be the first study to investigate the relationship between the pre-treatment, predicted and achieved outcomes regarding the number of occlusal contacts related to the Invisalign® Lite appliance.
- The Invisalign® Lite appliance comprised 2% of the overall caseload for the orthodontists who contributed to the database.
- Refinement was required in 70% of patients initially screened by this investigation.
- For minor tooth movement treatment using Invisalign® Lite, more than a 50% loss of posterior contact was observed in the achieved outcome compared to the initial and prescribed occlusal contact numbers.
- Minimal differences between the predicted and achieved anterior occlusal contacts were found.
- Future investigation is required to determine the treatment planning, aligner material and patient factors that result in the deficiencies regarding occlusal contacts and CAT appliances.

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Conflict of interest
The authors declare that there is no conflict of interest.

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