Invisalign Treatment: Analysis of Perimeter and Depth Modifications on Teeth Arches

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Abstract: Background: The request from patients for treatment with clear aligners is constantly increasing. The aligners can offer to the clinicians a way to solve a lot of malocclusions but the patients' compliance and the clinicians' capabilities and knowledge of the technique plays a key role. For this reason is fundamental to investigate all the changes that happen during a treatment with clear aligners.

Methods: To evaluate the modifications from t0 (beginning of treatment) to t1 (end of treatment).

Results: The arch depth and the arch perimeter decrease from t0 to t1 and the most relevant difference was observed in the upper arch depth with a decrease of 1.3mm and in the upper arch perimeter with a difference of 1.1mm.

Conclusions: At the end of a treatment with clear aligners there is always a decrease of the values of arch depth and arch perimeter. In the upper arch the differences are higher. It is necessary that the clinician consider these changes to perform a better treatment to obtain the most predictable results and higher satisfaction for the patients.

Keywords: Aligners, Invisalign, Arch depth, Arch perimeter.

1. INTRODUCTION

Orthodontic treatments with clear aligners are increasingly required, and a growing number of clinicians use it to solve malocclusions problems [1,2]. One of the most commonly known systems now is the Invisalign alignment system [3], which involves the use of a set of removable aligners as a valid alternative to fixed orthodontic treatments [4,5]. One of the limitations of this kind of treatment is the need for patient compliance, which must wear a clear aligner for at least 22 hours a day in order to obtain the previewed outcome [6].

It results from the literature that these systems are mostly effective in solving light and medium malocclusion [7]. For this reason the purpose of this study is to analyse how perimeter and arch depth varies in patients treated with aligners analysing the digital models in STL files [8] at the beginning of the treatment (t0) versus the outcome at the end of the treatment (t1).

2. METHODS

This retrospective cohort study the upper and lower arches of 15 consecutive patients (8 females and 7 males) treated with Invisalign Lite aligners by a single certified Invisalign (platinum elite) operator using SmartTrack aligners are evaluated.

Sixty digital models were analysed by placing 1440 spatial coordinates on 720 dental elements through the software VAM (Vectra, Canfield Scientific, Fairfield, NJ).

The virtual models of STL files obtained from PVS impressions were exported directly through the Clincheck software to avoid distortions due to the use of different scanners.

Patients with openbite, deepbite, molar and skeletal class that differs from the first class were excluded, as they could affect the results [9,10] and only patients with light and mid malocclusions that could be treated with invisalign Lite were included. The inclusion of the only first Angle class malocclusion is a limitation for the clinical study, however in a different situation with a stronger malocclusion or skeletal discrepancy between maxillary bone and mandible could be difficult to provide a general result.

Invisalign Lite provides a correction of malocclusion with only 14 aligners and the therapy is naturally limited to medium and simple degree of crowding resolution, regardless of dental grade correction. For light mal-
occlusion is considered a crowding from 2 to 4 mm; for mid malocclusion is considered a crowing of 4 to 6 mm.

The average values of overjet were 3 mm at the beginning of the treatment.

All patients between 13 and 28 years old and mean age of 19.3 had no previous orthodontic treatment and were not patients to be treated surgically to correct their malocclusions.

The duration of the treatment was for all the selected patients 14 weeks, changing one aligner per week.

Optimized attachments were bonded for all patients as needed and requested from the Clincheck starting from the aligner number 3.

Interproximal stripping (IPR) was performed as required by the Clincheck during the third clinical session. The average value of performed stripping was 0.5 mm in the upper arch and 0.8 mm in the lower arch.

It was thus possible to calculate arch perimeter and arch depth differences between the initial digital models, corresponding to the first impression and the final digital models corresponding to the refinement impression.

The inclusion and exclusion criteria are: patients in permanent dentition, patients older than 12 years, patients with no extraction, non-surgical patients, patients with only natural dentition without implants or removable prostheses, patients with a unilateral or bilateral Angle II or III class were excluded, patients with systemic diseases, moderate or severe skeletal discrepancies were excluded, mixed treatment patients were excluded.

Compliance was very high, as reported in several studies [10] in adult patients is easier to obtain higher collaboration and the selected patients stated that they wore aligners for at least 22 hours a day for the whole duration of the treatment. In all cases, the transition to the next aligner took place weekly for a total of 14 weeks of treatment.

The digital models were obtained by digital scans of Polivinylsiloxane (PVS) impressions downloaded from the Invisalign software (Clincheck Pro vers 5.1) to have an uniform acquisition source (PVS) and visual representation of the three-dimensional models (Clincheck).

STL files when downloaded from Invisalign Clincheck vers. 5.1 were uploaded to the VAM software (Vectra, Canfield Scientific, Fairfield, NJ), which was used to create the measurement files by positioning 24 points according to the following protocol by a single trained orthodontist (Invisalign Platinum provider):

- 2 points for each incisive tooth (a point on the incisal margin mesial and a point on the distal incisal margin)
- 2 points for each canine tooth (a mesial and a distal point to the height of the marginal edge of the element)
- 2 points for each premolar tooth (a mesial and a distal point on the occlusal surface at the pit)
- 2 points for the first molar (a mesial point and a distal point on the occlusal surface at the margins of the pits at the marginal mesial and distal ridges).

The operator arranged points as per protocol for 2 times on each model (on 10 models) to calculate intraoperative error through the Dahlberg formula [11] which was 0.2mm.

The depth of the arch was obtained by measuring the length of a perpendicular line constructed from the mesial contact point of the central incisors to a line connecting the mesial points of the first molars [12]. The mesial contact point of the central incisors was calculated as the midpoint between the mesial points of the central incisors (Figure 1).

Figure 1: Arch depth at t0.

The perimeter of the arch was calculated as the sum (on XY plane) of six segments (three by quadrant) ranging from the mesial point of the first molars to the mesial point of the first premolars, from the mesial point of the first premolar to the distal point of the incisors
lateral, and from the distal point of the lateral incisors to the mesial contact point of the central incisors (Figure 2).

![Figure 2: Arch perimeter at t0.](image)

Both the depth of the arc and the perimeter have been calculated as the segmental projection defined on the horizontal plane (XY plane), as described in the pre-existing literature [12].

The differences were tested with the p value and considered statistically significant for p <0.05.

3. RESULTS

The precision of the program used has also allowed to identify very small differences, which would be clinically meaningless, but statistically significant.

Therefore, threshold values for clinical relevance were established, referring directly to the American Board of Orthodontics (ABO) classification system (MGS).

Of the statistically significant differences, clinically significant ones were highlighted also when their value was above 0.05mm.

At time T0, the average depth of the upper arches is 27.4mm on average with a 4.0mm standard dev. At the end of treatment, the average depth of the arch was 22.5mm with a 1.9m standard dev. (Table 1).

<table>
<thead>
<tr>
<th>T1-T0</th>
<th>Avg</th>
<th>St Dev</th>
<th>LCI</th>
<th>UCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPTH</td>
<td>-1.3</td>
<td>3.5</td>
<td>-3.1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Based on these data it was possible to evaluate changes in the depth of the arch between the beginning and end of the treatment.

The difference between the depth of the average arc in T1 and T0 is -1.3mm with a 3.5mm dev standard and a confidence interval between -3.1mm and 0.5mm (Table 2).

Table 2: Differences between t0 and t1 for the Upper Arch Depth

<table>
<thead>
<tr>
<th>T0</th>
<th>T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>St Dev</td>
</tr>
<tr>
<td>DEPTH</td>
<td>27.4</td>
</tr>
</tbody>
</table>

At the beginning of treatment (T0), the lower average depth of the arch was 22.9mm with a 1.9m standard dev. At the end of treatment, the average depth of the arch was 22.5mm with a 1.9m standard dev. (Table 3).

Table 3: Average Values of the Lower Arch Depth

<table>
<thead>
<tr>
<th>T0</th>
<th>T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>St Dev</td>
</tr>
<tr>
<td>DEPTH</td>
<td>22.9</td>
</tr>
</tbody>
</table>

These values were correlated to obtain the differences between T1 and T0.

The difference between the lower arch depth in T1 and T0 is -0.3mm with a standard 1.2mm dev and a confidence interval between -0.9mm and 0.3mm (Table 4).

Table 4: Differences between t0 and t1 for the Lower Arch Depth

<table>
<thead>
<tr>
<th>T1-T0</th>
<th>Avg</th>
<th>St Dev</th>
<th>LCI</th>
<th>UCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPTH</td>
<td>-0.3</td>
<td>1.2</td>
<td>-0.9</td>
<td>0.3</td>
</tr>
</tbody>
</table>

The averages for the upper arch perimeters have been calculated with their respective standard dev for time T0 and time T1.

At time T0, the average perimeter was 68.8mm with a standard dev. of 3.7mm, at the time T1 was 67.7mm with a standard dev. of 4.2mm (Table 5).

Table 5: Average Values of the Upper Arch Perimeter
The difference between the average value of the arc perimeter in T1 and those in T0 is -1.1mm with a standard dev of 3.1 and a confidence interval between -2.7mm and 0.4mm (Table 6).

Table 5: Average Values of the Upper Arch Perimeter

<table>
<thead>
<tr>
<th></th>
<th>T0</th>
<th>T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>68.8</td>
<td>67.7</td>
</tr>
<tr>
<td>St Dev</td>
<td>3.7</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Table 6: Differences between t0 and t1 for the Upper Arch Perimeter

<table>
<thead>
<tr>
<th></th>
<th>T1-T0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>-0.1</td>
</tr>
<tr>
<td>St Dev</td>
<td>1.1</td>
</tr>
<tr>
<td>LCI</td>
<td>-2.7</td>
</tr>
<tr>
<td>UCI</td>
<td>0.4</td>
</tr>
</tbody>
</table>

At time T0, the lower arch perimeter is 62.9mm with a 4.9mm dev standard. At time T1 results to have a measurement of 62.6mm with a dev standard of 4.4mm (Table 7).

Table 7: Average Values of the Lower Arch Perimeter

<table>
<thead>
<tr>
<th></th>
<th>T0</th>
<th>T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>62.9</td>
<td>62.6</td>
</tr>
<tr>
<td>St Dev</td>
<td>4.9</td>
<td>4.4</td>
</tr>
</tbody>
</table>

The difference between the average value of the arc perimeter in T1 and T0 is -0.4mm with a standard 1.4mm dev and a confidence interval between -1.1mm and 0.3mm (Table 8).

Table 8: Differences between t0 and t1 for the Lower Arch Perimeter

<table>
<thead>
<tr>
<th></th>
<th>T1-T0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>-0.4</td>
</tr>
<tr>
<td>St Dev</td>
<td>1.4</td>
</tr>
<tr>
<td>LCI</td>
<td>-1.1</td>
</tr>
<tr>
<td>UCI</td>
<td>0.3</td>
</tr>
</tbody>
</table>

4. DISCUSSION

Other studies in literature in which measurements of the end of orthodontic treatment with aligners have been conducted include the use of measurement systems such as the Tooth Measure program present in the Clincheck itself [13-16], the ABO MGS system [17,18], the Surfacer Software [19], or the use of computerized tomography CBCT [16].

In addition, this study attempts to minimize the possible bias that could have led to poor accuracy by selecting cases handled by a single operator and performing the measurements to the same operator by calculating the margin of error.

Unlike other studies, the sample is as uniform as possible, there are no differences in the duration of treatment (14 weeks for each patient) and all aligners are in SmartTrack™ material, which guarantees greater elasticity, a fit of the arch much more accurate and manages to transfer a much more constant force than the past (Align Technology, 2016).

In addition, we only wanted to analyse Lite cases, with only mild and moderate crowding in which there was no influence on any class elastic or other devices [20].

To avoid further distortions due to different scanning systems, all polyvinyl siloxane imprints were sent to Align Technology and once scanned them were downloaded from the Clincheck.

Many values were statistically significant, but these variations are of such moderate magnitude that they would not have any clue in clinical practice. Therefore, only variations greater than 0.5mm are considered clinically relevant.

These data should be interpreted with caution because the required amount of displacements required was minimal as well as the required expansion was minimal. It is therefore presumed that in more complex treatments and with the use of a larger number of aligners, discordances may increase. It will be interesting to compare these results with other results of different authors but at the moment there are not similar studies in literature.

A decrease in the depth of the upper arc of 1.3mm has been observed between time t0 and time t1, while in the lower arch the depth is diminished, but reduced to only 0.3mm (Figure 3).

As for the arc perimeter, this is decreased by t0 to t1 of 1.1mm in the upper arch, while in the lower arch the decrease is smaller. A decrease of 0.4 mm has been recorded (Figure 4).

5. CONCLUSIONS

The scientific literature regarding studies of the dimensional changes obtained with the use of clear...
aligners is poor, for this reason the increasing demand for Invisalign treatments must push the clinician to know how these dental aligners perform during the treatment in order to make the correct decisions and to know the effect at the level of linear variations.

We should also consider the beneficial aspects of the good oral hygiene management guaranteed by the Invisalign device [21].

REFERENCES


Figure 3: Arch depth at t1.

Figure 4: Arch perimeter at t1.

There were decreases in both the depth of the arch and the arch circumference.

The greatest decrease in the arch depth was recorded in the upper arch with a variation of 1.3mm between t0 and t1.

As for the arch perimeter this has decreased between t0 and t1 of 1.1 mm in the upper arch.

The clinician must consider these changes to obtain the desired and programmed results.


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