Maxillary expansion with clear aligners in the mixed dentition: A preliminary study with Invisalign® First system

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Abstract

Aim The aim of this study was to evaluate maxillary arch changes in patients treated with Invisalign® First system in the mixed dentition, focusing on arch width, arch perimeter, arch depth, molar inclination and alveolar expansion.

Materials and methods A retrospective study was carried out. The sample consisted of 20 patients, 12 females and 8 males, treated with clear aligners for maxillary expansion. Arch widths, arch perimeter, arch depth and molar inclination were measured on pre-treatment and post-treatment digital dental models. Superimposition of digital models was performed to evaluate alveolar expansion.

Results There were significant increases in all measurements regarding arch width and arch perimeter, while arch depth and molar inclination significantly decreased. Alveolar expansion was recorded at all the reference points considered. Shapiro-Wilk test was used to check normal distribution. Average and standard deviations were calculated for all measurements. Paired t-test was run to report significant changes between T0 and T1. The statistical significance was set at $p<0.05$. Intraclass correlation coefficient was used to assess reliability.

Conclusions In case of mild crowding or limited transverse maxillary deficiency, Invisalign® First clear aligners could be a reasonable alternative to traditional slow maxillary expanders.

KEYWORDS Palatal expansion technique; Maxillary expansion; Clear aligner appliances; Mixed dentition.

Introduction

Maxillary transverse deficiency represents one of the most common skeletal deformities of the craniofacial region [Kiliç and Oktay, 2008]. Maxillary expansion has been performed for more than a century not only to correct transverse deficiencies but also to expand arch perimeter and alter the anatomy and the function of the nasal cavity [Bouserhal et al., 2014]. In general, treatments can be classified into slow maxillary expansion (SME) and rapid maxillary expansion (RME). Slow expansion occurs with lower forces distributed over longer periods while rapid maxillary expansion occurs by applying heavy forces over short periods of time, thereby producing immediate and significant effects on the maxillary transverse dimensions [Huynh et al., 2009]. In the last decades, an increasing number of patients are seeking for more aesthetic and comfortable alternatives to conventional orthodontic fixed appliances [Melsen, 2011], and also teenagers and children have become more reluctant to undergo fixed-appliance treatment for social reasons [Tuncay et al., 2013]. In 2018, Align Technology Inc. introduced Invisalign® First clear aligners, designed specifically for younger patients in the early mixed dentition. According to Align Technology Inc., the device can be used to perform phase I of orthodontic treatment, including the correction of a narrow maxillary arch. However, maxillary expansion with this treatment option has never been investigated in patients with early mixed dentition. The aim of this study was to evaluate dentoalveolar changes in patients treated with Invisalign® First clear aligners in the mixed dentition focusing on maxillary arch width, arch perimeter, arch depth, molar inclination and alveolar expansion.

Materials and methods

This work has been performed in accordance with the ethical standards established in the Declaration of Helsinki of 1975. Signed informed consent was obtained for all the patients. The sample of this retrospective study consisted of 20 patients, 12 females and 8 males, treated with Invisalign® First (Align Technology Inc., Tempe, AZ, USA) system. The mean age was 8.9 year and ranged from 6.9 to 11.2, while average treatment time was 8 months. The first aligner was worn for 14 days and then aligners were changed weekly. The mean number of aligners was 33.

The inclusion criteria for this study were as follows.

- Age between 6 and 12 years old.
- Mixed dentition.
- Erupted maxillary first molars.
- Planned arch expansion to be performed with Invisalign® First treatment.
- Adequate diagnostic records.

Subjects with one of the following characteristics were excluded from the study:

- Previous orthodontic treatment.
- Presence of complex malocclusion.
- Presence of craniofacial abnormalities or syndromes.
- Extraction cases.

Pre-treatment (T0) and post-treatment (T1) dental digital models, obtained from an iTero® (Align Technology Inc., Tempe, AZ, USA) intraoral scanner, were compared in order to evaluate arch changes. Digital .stl files were uploaded into a three-dimensional digital parametric inspection software (GOM Inspect 2019, Braunschweig, Germany).

The following measurements were recorded (Fig. 1, 2).

Canine gingival width (PC): linear distance between the centre of the palatal surface of the upper canines in contact with the gingival margin.

First deciduous molar gingival width (PD): linear distance between the centre of the palatal surface of the first deciduous upper molars in contact with the gingival margin.

Second deciduous molar gingival width (PE): linear distance between the inner point of the palatal surface of the first deciduous upper molars in contact with the gingival margin.

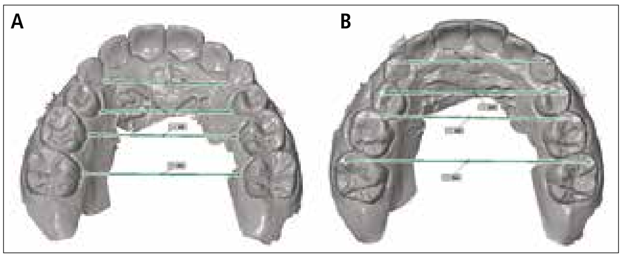

FIG. 1 Arch width linear measurements. A: Gingival level. B: Cuspids level.

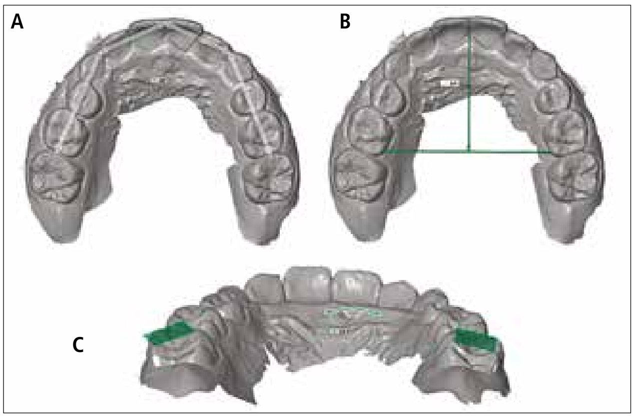

FIG. 2 A: Arch perimeter. B: Arch depth. C: Intermolar angle.

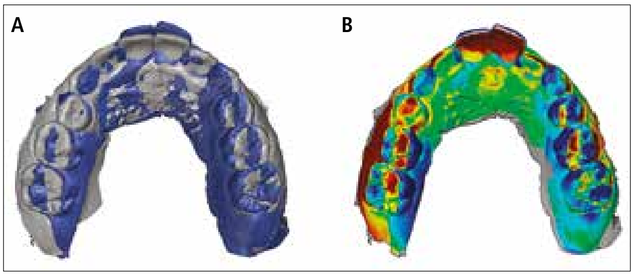

FIG. 3 A: Superimposition of digital models. B: Colour map generated from T0 model.

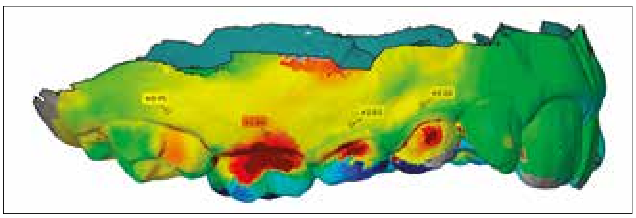

FIG. 4 Deviations of T1 measured on the colour map generated from T0.

First permanent molar gingival width (P6): linear distance between the inner point of the palatal surface of the first permanent upper molars in contact with the gingival margin.

Canine dental width (DC): linear distance between the cusp tips of the upper deciduous canines.

First deciduous molar dental width (DD): linear distance between the cusp tips of the deciduous upper first molars.

Second deciduous molar dental width (DE): linear distance between the mesio-buccal cuspids of the second deciduous upper molars.

First permanent molar dental width (D6): linear distance between the mesio-buccal cuspids of the first permanent upper molars.

Arch perimeter (AP): length of a line passing through the mesial aspect of first permanent upper molars, mesial aspect of deciduous upper canines and mesial aspect of central incisors.

Arch depth (AD): length of a perpendicular line constructed from the mesial contact points of the central incisors to a line connecting the mesial contact points of the first molars.

Intermolar angle (IMA): angle formed by the intersection between the two planes passing through the mesio-buccal, mesio-palatal and disto-buccal cuspids of both upper first molars.

The superimposition of 3D digital maxillary models was performed using palatine rugae as a reference area. A colour map was used to graphically represent differences between T0 and T1 (Fig. 3).

To evaluate alveolar changes, the deviation from T0 to T1 was calculated from the superimpositions, by measuring reference points located 2 mm above the gingival margin. Measurements were taken for deciduous upper canines (AC), first deciduous upper molars (AD), second deciduous upper molars (AE) and first permanent upper molars (A6) (Fig. 4).

Statistical analysis was performed. Shapiro-Wilk test was used to check whether data were normally distributed. All measurements were calculated as average and standard deviations. Paired t-test was run to report any significant changes between measurements from T0 and T1. The statistical significance was set at $p<0.05$. On 20% of the sample, measurements were taken twice by the same operator after 7 days. Intraclass correlation coefficient (ICC) was used to assess reliability, showing a high degree of reliability (ICC>0.97 for all measurements).

Results

Results are summarised in Table 1 and 2. For this study, 20 pre-treatment and post-treatment digital dental models were evaluated. The average duration of treatment was 8 months and the average number of clear aligners used was 33. All measured values showed a statistically significant variation between T0 and T1 (p-value<0.05). Intercanine width showed an average increase of 2.8 mm at cusp tips level and of 2.01 mm at gingival level. At first deciduous molars, an average increase of 3.28 mm was observed at cusp tip level, and of 2.24 mm at gingival level. At second deciduous molars, an average increase of 3.72 mm was observed at cuspid level and of 2.59 mm at gingival level. For the upper first permanent molars, the amounts of expansion achieved at cuspid level and gingival level were 3.05 mm and 2 mm, respectively. Arch

Variables	T0		T1		T1 - T0		p-value
	Mean	SD	Mean	SD	Mean	SD	
Canine dental width	32.71	1.81	35.51	2.23	2.8	1.51	<0.00001
First deciduous molar dental width	39.03	2.73	42.3	3.25	3.28	1.28	<0.00001
Second deciduous molar dental width	44.43	2.48	48.15	3.35	3.72	1.47	<0.00001
First permanent molar dental width	50.66	2.71	53.7	3.05	3.05	1.55	<0.00001
Canine gingival width	26.34	1.74	28.35	1.98	2.01	0.84	<0.00001
First deciduous molar gingival width	28.04	2.47	30.43	3.07	2.24	0.9	<0.00001
Second deciduous molar gingival width	30.43	2.17	33.02	2.92	2.59	1.12	<0.00001
First permanent molar gingival width	33.16	2.12	35.16	2.3	2	1.02	<0.00001
Arch perimeter	77.76	3.54	78.61	3.08	0.85	1.63	<0.05
Arch depth	28.94	2.05	27.7	1.58	-1.24	1.06	<0.00001
Molar inclination	155.18	7.96	150.56	7.48	-4.62	6.61	<0.01

TABLE 1 Comparison between T0 and T1 measurements.

	Alveolar expansion	SD
Deciduous canines	+ 1.88	1.08
Deciduous first molars	+ 1.6	1.16
Deciduous second molars	+ 1.4	0.96
Permanent first molars	+ 1.16	0.58

TABLE 2 Alveolar expansion.

perimeter increased of 0.85 mm, while arch depth decreased of 1.24 mm. The molar inclination decreased by 4.64 degrees. Alveolar expansion was detected at every reference point considered on the superimpositions. At deciduous upper canines the deviation was 1.88 mm, at first deciduous upper molars 1.6 mm, at second deciduous upper molars 1.4 mm, at first permanent upper molars 1.16 mm.

Discussion

The purpose of this study was to evaluate maxillary arch changes achievable with Invisalign® First treatment, focusing on arch width, arch perimeter, arch depth, molar inclination and alveolar expansion.

Invisalign® First, launched by Align Technology Inc. in 2018, is a treatment option designed to perform phase 1 of orthodontic treatment with clear aligners. Phase 1 treatment, traditionally done through arch expanders, lingual arches and functional appliances, represents early interceptive orthodontic treatment for growing patients in the mixed dentition. A correct management of orthodontic phase 1 allows early improvements of malocclusions and clear the path for orthodontic phase 2. The use of clear aligners enables movements on the three space dimensions simultaneously, allowing to correct different issues at the same time, including dental crowding, diastema, deep bite, open bite and increased overjet.

Compared with traditional fixed appliances, clear aligners represent a more aesthetic and comfortable alternative [White et al., 2017]. Furthermore, the use of removable appliances minimises the negative effects of fixed orthodontics on the periodontium and allow better oral hygiene [Jiang et al., 2018].

The correction of transverse maxillary deficiencies in growing patients is typically done with RME or SME. It has been reported that the range of expansion obtainable with both these treatment techniques is 2.49–3.58 mm for intermolar width and 2.27–2.64 for intercanine width (after retention) [Zhou et al., 2014].

Only a few studies have investigated maxillary transverse expansion with clear aligners [Houle et al., 2017; Zhou and Guo, 2020; Solano-Mendoza et al., 2017], and only one study has been published on Invisalign® First [Blevins, 2019]. Nevertheless, expansion using clear aligners represents one of the most discussed topics in modern orthodontics.

In permanent dentition, arch expansion can be performed with Invisalign®, but the increase in arch width is mainly achieved by tipping movements [Zhou and Guo, 2020]. The discrepancy between expected and achieved expansion with Invisalign® has been investigated. According to Houle et al. [2017], the mean accuracy for expansion movements for the upper arch is 72.8%: 82.9% at the cusp tips and 62.7% at the gingival margins. Zhou and Guo [2020] reported that the efficiency of crown expansion ranges from 68.31% to 79.75% while the efficiency of bodily expansion movements for the maxillary first molars is 36.35%. Solano-Mendoza et al. [2017] reported that expansion at the end of treatment is not predictable due to the differences between the planned ClinCheck® and the final 3D digital models.

In this study, all measurements have been recorded on 3D digital models. The use of digital dental models offers many advantages in terms of storage, retrieval, durability, diagnostic versatility and transferability [Asquith et al., 2018]. The accuracy of linear measurements on digital models has been thoroughly tested so far and is considered adequate [Sousa et al., 2012]. Moreover, a recent study concluded that measurements of buccolingual inclination are reliable and precise [Nouri et al., 2014].

The method used for the measurements was similar to that proposed by Solano-Mendoza et al. [2017]. Transversal widths were measured at the cuspids and at the cervical margins in order to evaluate bodily translation.The maxillary arch widths of the patients were significantly wider after the treatment. The greatest increases were achieved at deciduous molars, showing an average increase of 3.28 mm at cusp tip level, and of 2.24 mm at gingival level for deciduous first molars and an average increase of 3.72 mm at cuspid level and of

2.59 mm at gingival level for deciduous second molars.

Intercanine widths increased the least, 2.8 mm at cusp tips level and of 2.01 mm at gingival level. Arch width at permanent molars increased of 3.05 mm at cuspid level and of 2 mm at gingival level.

A consistent amount of bodily expansion was observed for canines, deciduous molars and permanent first molars.

Molar inclination has been recorded for its correlations with periodontal damages and vertical dimension. It has been established that excessive buccal tipping can lead to reductions in alveolar bone crest levels, bone dehiscences and gingival recession [Engelking and Zachrisson, 1982; Steiner at al., 1981]. The amount of buccal tipping observed with this expansion protocol is of 4.62 degrees, comparable with other slow maxillary expanders [Huynh et al., 2009].

A significant loss in arch depth was observed (1.25 mm), due to a redistribution of teeth along the arch and to a palatal movement of central incisors. For the same reason, the increase in the arch perimeter was minimal (0.76 mm).

Superimpositions of 3D digital dental models are a very useful tool to assess morphological changes due to growth, treatment, and pathology. Digital models have been superimposed on the palatal rugae [Stucki and Gkantidis, 2019], which can be considered a stable region during SME [Lanteri et al., 2020]. Although the validity of this technique for the assessment of alveolar expansion is still under evaluation, the results of this study showed an increase at all the reference points considered. The alveolar expansion recorded at deciduous upper canines was 1.88 mm, at first deciduous upper molars 1.6 mm, at second deciduous upper molars 1.4 mm, at first permanent upper molars 1.16 mm.

We may speculate that the forces generated with Invisalign® First system lead to a physiological adaptation comparable with slow maxillary expanders.

This study is not without limitations. The main problems are the absence of a control group and the small size of the sample. Cone-beam computed tomography (CBCT) is considered the gold standard for accurate anatomical measurements, providing a more extensive evaluation of maxillary deficiencies. Indeed, radiation exposure is relevant and not all the patients of this study required a CBCT as part of their orthodontic diagnosis. Nonetheless, the quality of the digital 3D dental models obtainable with CBCT is much lower compared to that from current intraoral scanners [Gkantidis et al., 2015].

Conclusion

In case of mild crowding or limited transverse maxillary deficiency, Invisalign® First clear aligners could be a reasonable alternative to traditional slow maxillary expanders. The results of this preliminary study demonstrate the efficiency of clear aligners for increase arch width in patients in the mixed dentition. The main advantages of this treatment lie in its comfort and aesthetics, in the reduction of the risk of additional appointments and in the better oral hygiene compared to fixed appliances. Further studies need to confirm the findings.

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