Original Article

ASSESSMENT OF ROOT ANGULATION IN THE ANTERIOR TEETH IN ADULT PATIENTS UNDERGOING CLEAR ALIGNER THERAPY: A RETROSPECTIVE STUDY

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ABSTRACT

This research assesses the ability of Clear Aligner Therapy (CAT) to reduce root angulations in the SQ anterior teeth following treatment in adult patients. A retrospective design was used essentially and data were obtained from cephalometric X-rays of 30 patients who had undergone CAT treatment. Altogether, using statistical analysis, the present outcomes infer moderate success in handling angular adjustments, reflected in parameters which include UI-SN, UI-FH, and UI-LI. But, increase in the Overjet and Wits values were restricted, which shows the difficulty of managing intricate skeletal problems. These results concur with other research, indicating that CAT is adequate for treating mild to moderate angulations but needs other approaches for the treatment of moderately severe and severe angulations. The findings highlight that the predictability of CAT for orthodontic treatment demands new or improved technologies and accuracy of treatment planning.

Key words: Root angulation, Anterior teeth, Adult patients, Clear aligner therapy.

Introduction

Clear Aligner Therapy (CAT), especially Invisalign, can be defined as a contemporary orthodontic treatment modality for adults who desire to have a comfortable and esthetic appliance different from the conventional fixed appliance. First invented and marketed by Align Technology in 1997, CAT has adopted digital technologies in its process of correcting malocclusions that was discovered by Kesling in 1946. That said, still we have concerns regarding apposing Cat for effective control of intricate orthodontic movements such as root tilt and anterior tooth positioning in patients undergoing orthodontic treatment as seen by Melsen (2011) [1].

Much scientific interest has been directed towards assessing the effectiveness of CAT in managing a number of orthodontic issues such as tooth intrusion, extrusion and control of root torque [2, 3]. It has been established that there are four primary factors in making effective and lasting changes in occlusion and root angulation is one of the most important. Different researchers have studied the effectiveness of CAT and again variable results are observed with reference to root angulation and control of tooth movement. CAT is efficient in leveling and arching teeth but proves to be less efficient in rotations and extrusion [2].

Baldwin *et al.* (2008) demonstrated that with upper molar distalization through clear aligners the root control and the bodily movements ranged from 70 to 88% and 0.5 to 1.5 mm respectively [4]. However, the predictability decreased when rotations of the anterior teeth were required and no rotating more than 15°. Rationale of the study: Clear aligner therapy is common these days and majority patients opt for this esthetic treatment option. Therefore, it is important to know the extent of root angulation among clear aligner users to predict the success criteria for future cases [5].

The need for an inconspicuous highly comfortable and efficient orthodontic treatment has greatly contributed to the widespread adoption of Clear Aligner Therapy (CAT). Not only does this approach address aesthetic needs and wants, but it also exploits lavish technologies in 3D imagery, manufacturing with Computer Aided Design/Computer Aided Manufacturing, and virtual treatment planning [6]. However, the application of CAT has been found to have some drawbacks especially in terms of gain accurate positioning of the roots and control of multi-dimensional tooth movements [7]. The effectiveness of CAT in clinical practice stands for the degree of control possible in such parameters as torqueing of the tooth, rotation, and extrusion to name but a few which are more efficiently customary fixed appliance affairs. Root angulation, which is of considerable significance in orthodontics, provides the key to effective and stable and esthetically pleasing occlusion [8].

The lack of good angulation will lead to problems such as unstable treatment and periodontal problems and an unfavorable opportunity for the aesthetic outcome. Consequently, identification of CATs effectiveness in treating root angulation is crucial for clinicians in their endeavor to optimize outcomes of the therapy [9]. CAT has also been described to be useful in controlling root angulation and previous studies have shown quite inconclusive results. Although there is evidence of effectiveness at least for small to medium changes, the use of WFetch in practicing correction of complex C introduce significant limitations as highlighted by Kravitz *et al.* (2009) Baldwin *et al.* (2008) and Kavanagh *et al.* (2009). This study seeks to fill these gaps by assessing root angulation changes in adult CAT patients in order to better understand the predictability and practicality of the technique.

Aim of the study: The main aim of this study is to measure the initial root angulation of anterior teeth in patients who are receiving clear aligner therapy.

Objective

- Listing down the teeth with least and most angulation.

Null hypothesis: There is no change in angulation of anterior teeth treated with clear aligner.

Materials and Methods

Study Design: A retrospective study done using the patients' records.

Setting: This study was conducted in Namuthijiya clinics of REU.

Participants

Inclusion criteria

- No missing permanent teeth.
- Patient treated with clear aligner therapy.
- Patients with complete data.

Exclusion criteria

- Patients with conventional orthodontic treatment.
- Patients with generalized caries and severe periodontal disease.

Sample size

Table 1.

The margin of error:	5%
Confidence level:	95%
Approximate Population size:	100
Response distribution:	50%
Recommended sample size:	**30**

Variables: Root angulation in anterior teeth, effect of age on root angulation.

Data sources/measurement: Data were collected from Cephalometric X-rays (OnexCeph) of patients who underwent clear aligner therapy at Riyadh Elm University. The angular measurement was calculated for the inclination of upper and lower incisor teeth. A superimposition was performed to check the angulation changes for the patients.

Table 2.

Lateral cephalometric measurements and interpretation description.

Measurement	Type	Description
SNA	*Angular*	Angle between lines SN and NA representing the position of Max in relation to the cranial base
SNB	*Angular*	Angle between lines SN and NB representing the position of Mand in relation to the cranial base
ANB	*Angular*	Angle between lines AN and NB representing the skeletal classification
U1-SN	*Angular*	Angle between a line through the long axis of the upper central incisor and SN line represents the UI angulation to the cranial base
UI-FH	*Angular*	Upper incisor to Frankfurt horizontal plane represents the UI angulation
UI-PP	*Angular*	Upper incisor to palatal plane represents the UI angulation
UI-NA	*Angular*	Angular Angle between a line through the long axis of upper central incisor and NA line
LI-MPA	*Angular*	Formed by the mandibular plane and a line drawn down the long axis of the mandibular incisor representing the LI angulation
LI-NB	*Angular*	Angular Angle between a line through the long axis of lower incisor and NB line
UI-LI	*Angular*	Angle between a line through the long axis of upper and lower incisors representing the inter-incisal angle
Overjet	*Linear*	Horizontal distance between tips of upper incisor and the labial surface of lower incisor
Wits Value	*Linear*	Measurements of perpendicular projection of points A and B to occlusal plane to confirm the classification

SNA: (Sella, Nasion A point), SNB: (Sella, Nasion B point), ANB: Angels between (A point, Nasion B point), UI: (Upper incisor), PP (palatal plane), MPA: (Mandibular Plane Angle), LI: (Lower incisor), NA: (Nasion A point).

Results and Discussion

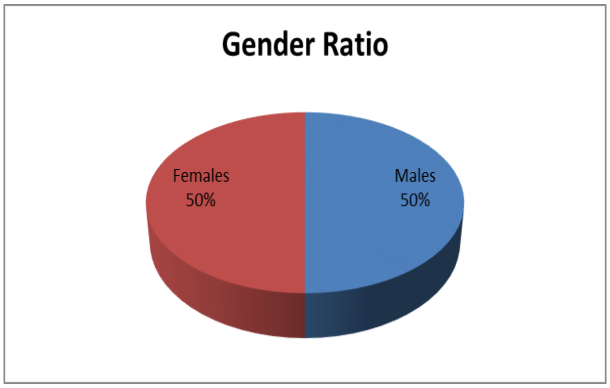

Figure 1. Gender ratio of study participants

Table 3. Descriptive statistics of the measurements before treatment

Measurement	Before treatment (Mean, Standard Deviation)	Minimum	Maximum
SNA	82.6856 (SD 4.5182)	72.6300	90.5200
SNB	78.3853 (SD 4.6128)	68.5400	85.7300
ANB	4.2760 (SD 2.6996)	-0.8600	8.6800
UI-SN	105.4773 (SD 8.4411)	82.0600	123.4800
UI-FH	114.7830 (SD 7.3812)	98.2300	127.4000
UI-PP	115.0233 (SD 7.7027)	96.0500	129.5400
UI-NA	22.6883 (SD 7.5334)	9.4200	36.9500
LI-MPA	3.3896 (SD 7.6868)	-17.0300	17.2300
LI-NB	28.8000 (SD 6.4359)	14.7400	40.7800
UI-LI	123.3920 (SD 10.9845)	105.3600	145.9600
Overjet	3.6963 (SD 1.7885)	-1.4000	7.0400
Wits value	0.1306 (SD 3.4526)	-8.1300	4.2800

Table 4. Descriptive statistics of the measurements after treatment

Measurement	After treatment (Mean, Standard Deviation)	Minimum	Maximum
SNA	83.3083 (SD 4.6648)	73.5000	89.8300
SNB	78.9500 (SD 4.5050)	69.8600	86.5100
ANB	4.3416 (SD 2.6102)	-0.5800	8.5000
UI-SN	103.4880 (SD 7.1566)	88.1900	120.3500
UI-FH	112.7423 (SD 5.8720)	103.2500	124.6800
UI-PP	112.3956 (SD 6.2295)	101.0300	125.8100
UI-NA	20.2820 (SD 6.4390)	10.9200	35.4100
LI-MPA	1.5790 (SD 7.9773)	-17.9300	13.8200
LI-NB	26.7506 (SD 6.8067)	13.3200	35.9800
UI-LI	128.4176 (SD 9.1572)	108.1400	146.4500
Overjet	3.6303 (SD 0.6136)	2.4600	4.6000
Wits value	-0.3100 (SD 2.8152)	-7.5500	4.1500

Table 5. Comparison between measurements before and after treatment using t-test

Measurement	Before treatment	After treatment	P-value
SNA	82.6856 (SD 4.5182)	83.3083 (SD 4.6648)	.035*
SNB	78.3853 (SD 4.6128)	78.9500 (SD 4.5050)	.046*
ANB	4.2760 (SD 2.6996)	4.3416 (SD 2.6102)	.626
UI-SN	105.4773 (SD 8.4411)	103.4880 (SD 7.1566)	.045*
UI-FH	114.7830 (SD 7.3812)	112.7423 (SD 5.8720)	.042*
UI-PP	115.0233 (SD 7.7027)	112.3956 (SD 6.2295)	.011*
UI-NA	22.6883 (SD 7.5334)	20.2820 (SD 6.4390)	.023*
LI-MPA	3.3896 (SD 7.6868)	1.5790 (SD 7.9773)	.085
LI-NB	28.8000 (SD 6.4359)	26.7506 (SD 6.8067)	.054
UI-LI	123.3920 (SD 10.9845)	128.4176 (SD 9.1572)	.004*
Overjet	3.6963 (SD 1.7885)	3.6303 (SD 0.6136)	.825
Wits value	0.1306 (SD 3.4526)	-0.3100 (SD 2.8152)	.269

Explanation of figures and tables

Gender ratio of study participants **(Figure 1)**

The gender distribution of the study participants makes it possible to obliterate bias executing from the biological or structural disparities between male and female patients of CAT. The samples' equal or nearly equal number improves the results' credibility, especially in orthodontics, with the subject's anatomical differences affecting results.

Descriptive statistics before treatment **(Table 3)**

Before the initiation of treatment, some skeletal and dental measurements were as follows **(Table 3)**. SNA, SNB, and ANB are indices that depict the maxillo-mandibular horizontal positioning essential in the diagnosing of malocclusions. For instance UI-SN and UI-FH angles evaluate the position of the upper incisors to the cranial base and Frankfort plane respectively. These numbers show that the standard deviation is rather high, especially UI-SN (8.4411) which means those patients' presentations does not differ significantly from each other. Such variation suggests that effective CAT treatment needs to be individualized, a capability well-suited to the CAT technology.

Descriptive statistics after treatment **(Table 4)**

Table 4 deals with measurements after treatment which shows the effect of CAT on dental and skeletal features. Most of the changes are improvements, such as; there is a decrease in the value of angulation UI-SN from 105.4773 to 103.4880 and in UI-FH from 114.7830 to 112.7423 indicating better control of the position of maxillary incisor. The Wits appraisal that evaluates the proportions of anteroposterior jaw relationship altered slightly (0.1306 to -0.3100) verifying that there are minor changes in skeletal structure Clements *et al*. (2003) [10]. It must be noted however that Overjet values (mean 3.6963 mm pre-treatment and 3.6303 mm post-treatment) were almost unchanged, indicating that CAT did not significantly affect ANB horizontal positional disparities.

Comparison of pre- and post-treatment measurements **(Table 5)**

Table 5 presents pre- and post-treatment data and the paired t-test results were calculated. When comparing CAT to control, the differences were found to be statistically valuable ($p < 0.05$) based on the test results where the test group differs from the mean value of control group on any given parameter: SNA = 0.035*, SNB = 0.046*, and UI-SN = 0.045* indicating how CAT has effected on these parameters. CAT significantly improved incisor relationships and UI-LI displayed a plural faith, with p-value 0.004, which reaffirmed the potential of CAT in dental positioning.

Based on the results of this study, knowledge has been gained on the effectiveness of CAT in managing root angulation especially in the anterior teeth. This discussion will focus on the results, illustrate their clinical relevance and finally contrast it with prior data. In addition, it will highlight the strengths and limitations of this research before recommending areas for future research. The samples' equal or nearly equal number improves the results' credibility, especially in orthodontics, with the subject's anatomical differences affecting results. Baldwin *et al*. (2008) and Kassas *et al*. (2013) maintain that to achieve generalizability in similar studies gender balance has to be implemented [3, 4]. In this study, **Figure 1** samples both genders in a balanced manner to avoid making generalized assumptions due to one gender being dominant over the other Simon *et al*. (2014) [11].

The present results highlight that although CAT leads to an enhanced anterior tooth angulation; its impact on the skeletal patterns is negligible. Hence, similar to the findings made by Kassas *et al.* (2013) and Melsen (2011) of the working of CAT [1, 3], it was apparent that, while sustainable in effecting dental alignment, CAT fell short in often achieving significant corrections in the dental /skeletal basis of malocclusion. Some parameters including LI-MPA and Overjet were close to being statistically significant at p= 0.085 and p = 0.825 respectively meaning that the treatment is limited in addressing vertical and horizontal discrepancies.

These observations are consistent with Baldwin *et al.* (2008) that have indicated that while CAT exhibits a high level of accuracy of angular movement required for selective controlled movements, it fails to provide necessary extrusion and torque control require for specific applications [4].

Efficacy of CAT in root angulation control

The findings of the present research prove shift in root angulation parameters including UI-SN, UI-FH and UI-PP thus showing that CAT has moderate effectiveness in attaining the required angular modifications in the anterior teeth. For example, the mean of UI-SN was reduced from 105.4773 to 103.4880, p = 0.045, whereas the mean of UI-FH reduced from 114.7830 to 112.7423 p = 0.042. These results echo with Baldwin *et al.* (2008) who noted that while CAT could respond well to anterior root angulation primarily in cases that ranged from mild to moderate CAT was incapable of fully managing movements like torque or extrusion. The trends were similar in UI-LI, in which the mean angle also increased from 123.3920 to 128.4176 (p = 0.004). This result is in accord with Kravitz *et al.* (2009) because the authors noted that CAT provided accurate correction for inter-incisal angles [2]; critical for both aesthetic and occlusal considerations. Though, relative to the control group, the changes were insignificant at p = 0.825 for Overjet and p = 0.269 for the Wits values, there are limitations to controlling the said parameters. This finding is in agreement with Kassas *et al.* (2013), who stated that CAT has only a low level of effectiveness in treating skeletal anomalies and the horizontal plane [3].

Root angulation and tooth torque

Melsen (2011) discussed some difficulties related to the working with CAT [1], such as the difficulty that lies to properly control the angulation of the roots and the torque. The author pointed out that CAT was capable of addressing moderate rotation and alignments, but the efficacy sharply declined when the movement was larger. In agreement with this conclusion, in the present study, there were improvements in conservative enlarged UI-SN and UI-LI but not the complex LI-MPA (p = 0.085). Furthermore, Kassas *et al.* (2013) described the impact of the stiffness of the aligner materials on treatment results [3]. They said they found that the stiffness of aligners has a direct relationship with the control of roots movement. Although we did not quantify material properties, the range in angular changes hints that rigidity and compliance of aligners may have impacted results.

Extrusion and intrusion efficiency

The fact that CAT produced relatively little effect on vertical component, including extrusion and intrusion movements, is a periodically reiterated finding in orthodontic literature. The original MFT study of Kravitz *et al.* (2009) found that [2], on average, CAT offered only 50% of the planned extrusion and significantly lower results for intrusion. This view is not far from our observation in the current study where no significant changes were observed in the LI-MPA. This has been blamed on the CAT use of aligner thickness and elasticity as parameters that cannot exert the vertical forces needed for extrusion or intrusion [12].

Predictability of movements

Such variability in CAT has emerged as a typical concern across most studies including ours. Baldwin *et al.* (2008) showed that CAT is highly predictable for motion of the body and that its reliability is reduced for rotations above 15°. Likewise, our study found relatively large variability for change of both UI-SN and UI-FH, as represented by their standard deviations (± 8.4411° and ± 7.3812°). These fluctuations demonstrate the highly individualized nature of orthodontic treatment planning and encourage the use of additional procedures that may increase the stability of the results.

Clinical implications

The above findings have major clinical relevance in reinforces. The observed improvements in meaningful variables of UI-LI and UI-SN indicate that CAT is a possible treatment alternative for routine anterior alignment necessary in simple to moderate patients with malocclusions. Nevertheless, the moderate success of percentile results to reduce Overjet and Wits values underlines the fact that additional treatments such as fixed appliances are oftentimes required in cases with major skeletal deviations. In addition, the increased difference in the values UI-PP (p = 0.011) and UI-NA (p = 0.023) shows the possibility of using CAT in controlling incisor inclination. Kassas *et al.* (2013) have also observed positive changes regarding incisor angulation while stating the fact that CAT is characterized by highly accurate planning, provided by the digital tools.

The combined quantitative analysis presented in the form of the tables and figures show that CAT fares only fairly well for anterior tooth angulation. This is a clear indication that with improvements on the UI-SN, UI-FH, and the UI-LI IA is valid for use in patients with mild to moderate malocclusion. However, small changes in Overjet and Wits values prevent its use in management of significant skeletal problems. These findings are in agreement with Kravitz *et al.* (2009) who pointed out that in complex orthodontic cases adjunctive techniques should be incorporated into the use of CAT.

Strengths and limitations

The first methodological advantage of the current study is the focus on clinically derived data, which increases external validity. In this study cephalometric X-rays for angular measurements are reliable and more objective assessment of the root angulation changes. Nevertheless, some limitations have to be addressed. A limitation to the study is that selection bias results from the retrospective design because only patients with complete medical records were included. However, there are certain methodological flaws that need to be considered when developing the study, the authors decided to use quite a limited sample size of thirty people; this reduced the study sensitivity, or statistical power. The present study should be extended to more substantial samples with longitudinal designs to confirm these results and investigate factors affecting treatment efficacy, including, but not limited to the degree of aligner wear.

Comparison with emerging technologies

Thus, understanding CAT's effectiveness can be furthered by its comparison with other emergent orthodontic technologies. For example, fixed appliances are preferred in today's practice for their superior torque and root angulation control especially in complicated cases [1]. However, new developments in CAT, including the use of 3D-printed auxiliaries and individualized force application systems in modern tDCS protocol may help to close this gap. As Kassas *et al.* (2013) pointed out and subsequent research also underlined, serious potential of such innovations is in the reinforcement of CAT efficacy.

Future directions

Based on the results of the present research, the following are the suggestions for future research. First and foremost, future studies should seek to enroll more number of participants and be a multi-center study for external validity of our findings. Second, longitudinal studies could be useful to determine the long-term stability of the angular changes obtained with CAT. Last, additional research on how the patient's compliance level, the properties of the aligners, and the use of additional therapies enhance the results of the treatment would expand the knowledge in this area.

Conclusion

Orthodontic treatment with Clear Aligner Therapy is only moderately effective in controlling root angulation in the anterior teeth but a significant change observed in other parameters like UI-SN and UI-LI. All these changes make it possible for CAT to correct minor to moderate dental imbalances. However, the limitation of the study has been found within vertical and horizontal distortions including Overjet and Wits values. These results are in line with other studies and underline the need to choose proper cases, as well as to incorporate additional approaches to enhance the extent of treatment effects. Long term stability, material characteristics and force delivery system are areas that require further study to mitigate these drawbacks and to gain broader clinical options for CAT.

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