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A comparative study of changes occurring in the transversal direction of the dental arch in patients suffering from moderate crowding after treatment with three different orthodontic techniques

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Abstract

The aim of this study was to study Clear Aligners technique efficiency in treating malocclusion and to know its limits and barriers, and to compare dental changes occurring in moderate crowding patients (4-7mm) with skeletal class I malocclusion. So we collected a sample consisted of 45 patients divided into three groups (15 patients treated with traditional fixed orthodontic appliances as control group, 15 patients treated with fixed orthodontic appliances using thermal naitinol archwires and 15 patients treated with clear aligners technique), after finishing orthodontic treatment casts were scanned by three dimensional scanner and radiographic images were taken for each patient and were compared with pretreatment patient data, dental changes were studied using a computer program, the measurements were compared for the three groups and we collected a lot of results, some of them was that changes occurring in the transversal direction of the dental arch was significantly greater in clear aligners group than both control group and the group treated using thermal naitinol archwires.

Keywords: Clear aligners, thermal naitinol, three dimensional scanner

Introduction

Orthodontic treatment is one of the most essential and effective way to make individual smile in to radiant and more attractive smile.

The word orthodontics came from two Greek words orthos' means normal, correct, or straight and 'dontos' means teeth. Correction of malocclusion by correcting and improving the position of teeth is main concern of orthodontist.

Sometimes patients are hesitant about the pain and discomfort related to brace, as well as metallic smile is a deterrent for style conscious young adults who want straighter teeth but refuses traditional metal orthodontics ^[1].

The field of orthodontics has been revolutionized by technological advancements in the last two decades.

Three-dimensional (3-D) imaging and modeling have expanded diagnostic and treatment planning abilities ^[2].

With all the advancements in the field of orthodontic still wearing braces has never been easier. The brackets appear ugly on the patient's smile, looking even dark on the teeth. It is very unattractive for any typical individual and it is even a more concerning issue for the individuals who are more established, who can't bear resembling a metal-mouth just to have straighter teeth ^[1].

The clear aligners therapy (CAT) has opened up a new area of adult orthodontics, serving patients who may not want conventional fixed appliances or for whom traditional removable appliances may be unsuccessful.

So clear aligners are the new age aesthetic orthodontic treatment methods developed especially for adults who are very self-conscious of how they appear ^[3].

Clear aligners technique and its aesthetic revolution has become an aesthetic alternative to metallic smiles, which are not that noticeable ^[4].

Clear aligners technique is a virtual orthodontic appliance that is utilized to straighten the teeth without support of an undetectable way.

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While clear aligners regularly asked for its aesthetic advantages, numerous patients don't understand that it additionally has various oral health advantages [1].

Although guidelines about the types of malocclusions that this technique can treat exist, few clinical studies have assessed the effectiveness of the appliance.

A few recent studies have outlined some of the limitations associated with this technique that clinicians should recognize early before choosing treatment options [5].

The history of clear aligners is back to 1945, when Dr H. D. Kesling first proposed a clear, vacuum-formed tooth-positioning appliance for minor tooth movement. It was a labor-intensive process that required manually repositioning teeth reset in wax, and a clear vacuum-formed retainer was made for every tooth movement in a series of stages until the teeth were aligned. This technique was capable of minor tooth alignment. However, the amount of labor required for the task precluded its use on a wide scale, particularly for correction of more complex malocclusions [6].

Another half-century went by until two graduate students at Stanford University in 1997 applied three-dimensional (3D) computer imaging graphics to the field of orthodontics and created the world's first mass-produced, customized clear aligners system. This new technology revolutionized the world of dentistry and orthodontics, launching it into the 21st century [5, 7].

In the early days of clear aligners, most clinicians understood them to be an orthodontic appliance that was suitable for the treatment of class I cases with minor crowding, resolved primarily with interproximal reduction [8]. Today, clear aligners are made of a new triopolymer plastic and make use of optimized attachments. The teeth are moved according to sophisticated computer algorithms developed in the software program. There are many clear aligners systems being developed all over the world, and it is evident that this will be the future of orthodontics [9, 10].

It is important to understand that clear aligners treatment is a technique, not a product. There is a common misconception that clear aligners are a "compromise" orthodontic appliance that is only capable of minor tooth movement. However, the clear aligners system of today is a comprehensive orthodontic appliance, capable of treating a wide range of malocclusions [11].

Some authors even doubt whether bodily movements or torque can be accomplished at all by aligners, and therefore recommend clear aligners therapy only in cases that require tipping movements [5].

But many of these connections were based only on theoretical and predictive studies on the possibilities of clear aligners technique without adding any clinical information to the amount of knowledge available on this subject in medical literature [2].

Hence, it is important to carry out clinical studies on the accuracy of clear aligners technique in achieving the results of the expected treatment, comparing them with the traditional methods of orthodontic treatment and investigating the differences between these different techniques in terms of the occlusal changes taking place as well as the acceptance of patients and the effect of these treatments on aesthetics and professional life among different age groups and different malocclusion types, hence the idea and justification of this research.

This is of significance since it has been suggested that clear aligners have limitations when it comes to producing certain tooth movements. For instance, questions have been raised

regarding the extent to which they can control extrusion, rotations, bodily movement and torque [4, 5].

Proffit *et al.* reported that forces required to produce rotation of a tooth around its long axis are similar to those required to produce tipping. This is due to the fact that the force could be distributed over the entire periodontal ligament rather than over a narrow vertical strip. It is thus impossible to apply a pure rotational force without a tipping movement of the tooth in its socket [12].

The present review suggests that clear aligners can produce both uncontrolled and controlled tipping movements. The uncontrolled tipping in closing extraction sites and the scarce results in tipping canines suggest that teeth with larger roots might have greater difficulty achieving mesiodistal movements. However, in another study clear aligners and fixed appliance treatment achieved similar results for root angulation at the end of treatment.

It is generally thought that aligners can easily tip crowns but cannot tip roots because of the lack of control of tooth movement [13, 14, 15].

Thus, it is possible that a greater percentage of the prescription should be achieved if the maximum 2-week activation was decreased to 0.25 mm or less instead of 0.5 mm. Thus, the experimental procedure did not reflect the daily clinical routine. On the contrary, Simon *et al.* reported a high accuracy (88%) of the bodily movement of upper molars when a distalization movement of at least 1.5 mm was prescribed. The authors reported the best accuracy when the movement was supported by the presence of an attachment on the tooth surface.

Furthermore, they underlined the importance of staging in the treatment predictability.

The contrasting results reported in the analyzed literature regarding the CAT tipping control might be due to the difficulties related to the application of a couple of force with this kind of appliances. Altered aligner geometries and attachments seem to be required in order to improve the root control. Thus, well-designed aligners are needed to clarify the real efficiency of CAT in moving crowns and root along the arch [16].

The results of one RCT and two retrospective studies agree in assessing the efficacy of CAT in aligning and straightening the arches, with better results for mild to moderate crowding when compared to the results obtained with fixed appliances [17, 18, 19].

In 2017 Gu and his assistants achieved a study, they examined the treatment effectiveness and treatment efficiency between clear aligners and fixed appliances. They concluded that final occlusal scores did not differ between the two techniques, and treatment with clear aligners was finished on average 30% (5.7 months) faster than treatment with fixed appliances.

However, the likelihood of achieving "great improvement" in a malocclusion appears to be better with fixed appliances [20].

Another study was achieved in 2017 by Houle and his assistants, the authors of this retrospective study evaluated the predictability of arch expansion using clear aligners.

The sample included 64 white adult patients with an average age of 31.2 years, who had both arches treated by one practitioner using clear aligners only.

Using this software's calipers, linear values of maxillary and mandibular arch widths were measured at the cusp tips and the most lingual points at the gingival margins of the canines, premolars, and first molars by the principal investigator.

The results showed that when expansion is planned with clear aligners, the mean accuracy for the maxilla was 72.8%, with

82.9% at the cusp tips and 62.7% at the gingival margins. In the mandibular arch, the mean expansion was 87.7%, with 98.9% at the cusp tips and 76.4% at the gingival margins. It seems to overestimate expansion by body movement; more tipping was observed. The authors recommend overcorrection of expansion when using clear aligners, especially in the posterior region of the maxilla [21].

Apical root resorption is considered one of the unwanted consequences of orthodontic tooth movement. There is paucity in the literature about the incidence of orthodontically induced root resorption with clear aligners compared to fixed appliances. So Eissa and his assistants presented a study that addressed the degree of apical root resorption following treatment with clear aligners as well as two different fixed orthodontic appliances; regular and Damon braces using Cone Beam Computerized Tomography (CBCT).

This study demonstrated that the use of clear aligners showed less root resorption relative to regular fixed or Damon appliances [22].

In general, clear aligners technique is able to achieve predicted tooth positions with high accuracy in cases with mild to moderate malocclusions. Clinicians may consider the following potential weaknesses when planning treatment with clear aligners:

1. Maxillary expansion may not be fully achieved
2. Rotation of rounded teeth tends to be incomplete
3. Torque of molars may not be fully achieved, with maxillary second molars often having clinically relevantly more buccal crown torque than predicted [2].

With appropriate and continuous education, training, and experience, orthodontists can achieve optimal treatment results for a wide range of malocclusion patterns using the clear aligners technique [23].

After this review of the above studies we found that many scientists were interested in the study of the clear aligners technique because it opens up a new horizon for cosmetic orthodontic treatments but it is still a modern technology that needs more and more clinical research to support its effectiveness and its real ability to achieve teeth movements and correcting malocclusions.

Among these studies, we did not find a study that compared the measurements and values which surveyed and statistically analyzed with the form and method in which adopted in our study, hence the importance of this study and its justifications. We compared the results of treatment for class I skeletal malocclusion patients with moderate crowding (treated without extraction), they were treated according to three different techniques (traditional fixed orthodontic appliances, fixed orthodontic appliances using thermal naitinol archwires and clear aligners technique).

The results of the three groups were compared to each other and then the results were compared between males and females within the studied groups to investigate the occurring changes according to a large number of measurements on three dimensional casts and radiographs of patients before and after orthodontic treatment.

Aim of the study

- Studying the effectiveness of the technique of clear aligners technique in adults in our society
- Studying the effectiveness of the clear aligners technique in the treatment of moderate crowding of malocclusion.
- Comparison of the changes in the cross-direction of the dimensions of the dental arch between the three groups

with each other (traditional fixed orthodontic appliance, fixed orthodontic appliance using thermal naitinol archwires and clear aligners technique).

- Comparison of the effectiveness of the clear aligners technique between the upper and lower jaw.

Materials and Methods

Study design

A clinical study on adult patients with moderate crowding and class I skeletal malocclusion.

Inclusion criteria

1. A Syrian national (Syrian father and mother) and a resident of the central region.
2. Age > 20 years, less than 50 years.
3. Patient in the stage of permanent occlusion.
4. The emergence of all permanent teeth (except for the third molar).
5. Patients with moderate crowding (4-7 mm).
6. Patients with class I skeletal malocclusion.
7. Gums around the teeth in a healthy and good condition.
8. The orthopedic tissues around the teeth on the panoramic image in good condition.
9. The safety of the mental state of the patient.
10. There are no functional deviations of the lower jaw.
11. There are no cross bites.
12. There are no open bites.
13. There is no clear clinical evidence of facial asymmetry.
14. There is no clear clinical evidence of TMJ disorders.
15. There are no congenital facial or congenital malformations.
16. Patients were not subjected to previous orthodontic treatment.

The study compared 45 patients who were divided into three different treatment groups:

Group I: included 15 patients treated with traditional fixed orthodontic appliances as control group.

Group II: includes 15 patients treated with fixed orthodontic appliances using thermal naitinol archwires

Group III: includes 15 patients treated with clear aligners technique.

The following clinical and radiological records were taken for patients:

1. Radiographic images

- Panoramic image before and after processing T1-T2
- Cephalometric image before and after treatment T1-T2

2. Photographic images

- Face images of the front and lateral position before and after treatment T1-T2
- Teeth images of the front and side occlusion and images of the occlusal view before and after treatment T1-T2

3. Rubber impression

The records of each patient were then examined to obtain the treatment plan accurately.

First: Radiographs study

On the panoramic image, the roots parallel were studied before and after treatment.

On the cephalometric image, the changes in many skeletal and dental angles were studied after the treatment. The Viewbox 4 program was used to study the digital cephalometric images.

Table 1: Shows the angular measurements included in the study (Jacobson, 1995)

The angular measurements included in the study		Table (1)
Measurement Type	Angle Code	Definition
Angular	SNA	Angle between SN and NA
Angular	SNB	Angle between SN and NB
Angular	ANB	Skeletal Angle
Angular	SN-Mp	Angle between SN and MP
Angular	SN-Max	Angle between SN and SPP
Angular	MM	Angle between MP and SPP
Angular	SN-Y	Angle between SN and Y axis
Angular	SN-I	Angle between SN and upper incisor axis
Angular	Mp-I	Angle between SN and lower incisor axis
Angular	I-I	Angle between lower and upper incisors axes

Second: Casts study

The maximum mesiodistal tooth dimension was measured in each arch except the second and third molars using the fine-grained spindle. The caliper was directed vertically on the long axis of each tooth.

Measurements of dental arches width:

The following measurements were taken at the beginning of the treatment and after the end of the treatment and the achievement of the class I relationships:

1. Intra canine dental width
2. Intra premolar dental width
3. Intra molar dental width

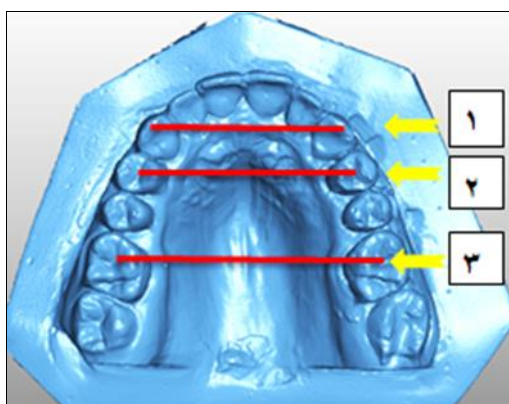


Fig 1: Measurements used in the study on casts

After determining the studied variables on the radiographs and the casts, we turn to explain how the research is done in detail.

Following the distribution of patients who met the criteria of entry into the three groups (traditional fixed orthodontic appliances group, fixed orthodontic appliances using thermal naitinol archwires group and clear aligners group) randomly, the fixed appliances were applied to patients whose names were selected in the control group which treated with traditional fixed orthodontic appliances

Brackets (MBT/0.22) were used

The following orthodontic archwires were applied on the upper and lower jaws:

- 0.12 NiTi
- 0.14 NiTi
- 0.16 NiTi
- 0.16*0.22 NiTi

- 0.17*0.25 NiTi
- 0.19*0.25 S.S

And the fixed appliances were applied to patients whose names were selected in the second group wick treated with fixed orthodontic appliances using thermal naitinol archwires. Brackets (MBT/0.22) were used.

The following orthodontic archwires were applied on the upper and lower jaws:

- 0.12 thermal NiTi
- 0.14 thermal NiTi
- 0.16 thermal NiTi
- 0.16*0.22 thermal NiTi
- 0.17*0.25 thermal NiTi
- 0.19*0.25 thermal NiTi



Fig 2: The two types of archwires (naitinol- thermal naitinol) used in the study

While rubber impression for patients of the clear aligners group were sent to the specialist laboratory for the initial conception of the treatment, the duration of treatment and the number of aligners required to complete the treatment (average 5-15 aligners).

All the values of the measurements mentioned above were then compared before and after treatment within the same group as well as between males and females and between the upper and lower jaw within the same group and then compared the three groups with each other.

In this article we will examine the following variables :

1. Intra canine dental width
2. Intra premolar dental width
3. Intra molar dental width

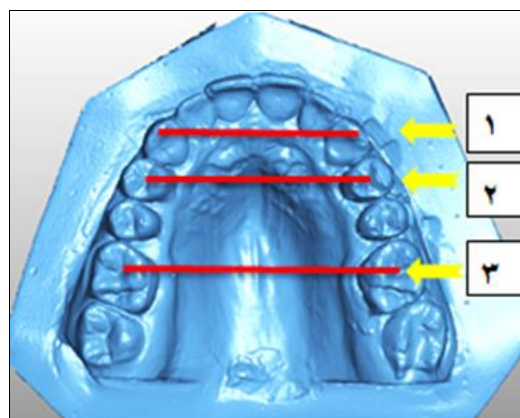


Fig 3: Figure of the measurements of dental arch width

Results

The distribution of the current study data was studied at the beginning. A test was conducted on whether the data follow normal distribution or not by applying the Z-Test for all the variables included in the study.

All statistical analyzes and tests were carried out and the necessary charts were created using the appropriate statistical analysis programs:

- World Statistical Analysis Program SPSS
- Statistical Package for Social Searches, Version 20
- M. S. Excel Version 12

Then we had the following results:

1. Results of the comparison between the intra canine dental width among the three groups:

The study of this variable on the upper jaw showed that both the clear aligners group and fixed orthodontic appliances using thermal naitinol archwires group showed significant

statistical differences when compared with the control group (which treated with traditional fixed orthodontic appliances) at the P value ($p < 0.05$) and the confidence level $\alpha = 95$. And the average of both previous groups was larger than in the control group.

While the study of this variable on the lower jaw showed that the clear aligners group showed significant statistical differences when compared with both the control group and the fixed orthodontic appliances using thermal naitinol archwires group at the P value ($p < 0.05$) and the confidence level $\alpha = 95\%$, and the average of clear aligners group was greater than in the remaining two groups.

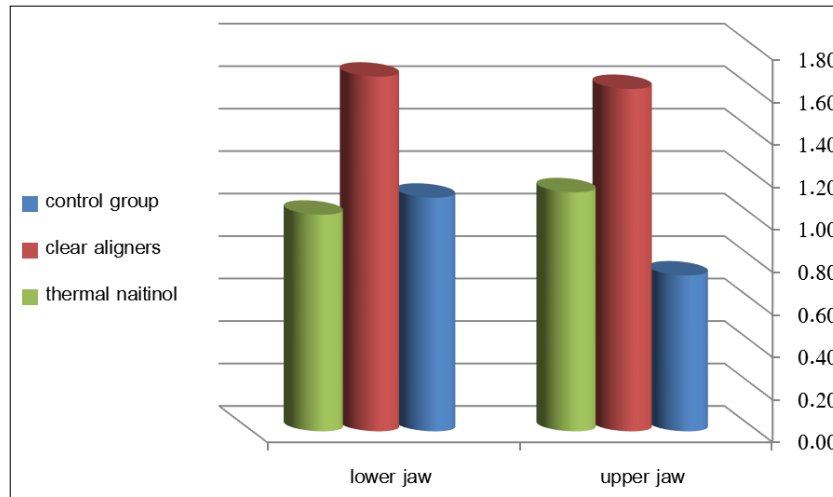


Fig 4: Figure shows the arithmetical averages of the amount of change in intra canine dental width among the three groups

2. Results of the comparison between the intra premolar dental width among the three groups:

The study of this variable on the upper jaw showed that the clear aligners group showed significant statistical differences when compared with the control group at the P value ($p < 0.05$) and the confidence level $\alpha = 95\%$, and the average of clear aligners group was greater than in the control group, while the other comparisons between the three groups did not show significant statistical differences.

While the study of this variable on the lower jaw showed that both the clear aligners group and fixed orthodontic appliances using thermal naitinol archwires group showed significant statistical differences when compared with the control group (which treated with traditional fixed orthodontic appliances) at the P value ($p < 0.05$) and the confidence level $\alpha = 95$. And the average of both previous groups was larger than in the control group.

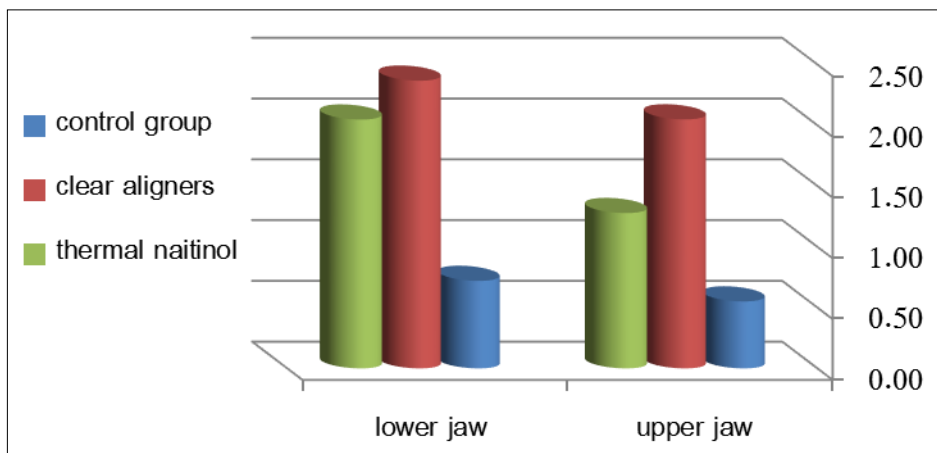


Fig 5: Figure shows the arithmetical averages of the amount of change in intra premolar dental width among the three groups

3. Results of the comparison between the intra molar dental width among the three groups:

The study of this variable on the upper jaw showed that the clear aligners group showed significant statistical differences when compared with both the control group and the fixed

orthodontic appliances using thermal naitinol archwires group at the P value ($p < 0.05$) and the confidence level $\alpha = 95\%$, and the average of clear aligners group was greater than in the remaining two groups.

While the study of this variable on the lower jaw showed that the clear aligners group showed significant statistical differences when compared with the control group at the P value ($p < 0.05$) and the confidence level $\alpha = 95\%$, and the

average of clear aligners group was greater than in the control group, while the other comparisons between the three groups did not show significant statistical differences.

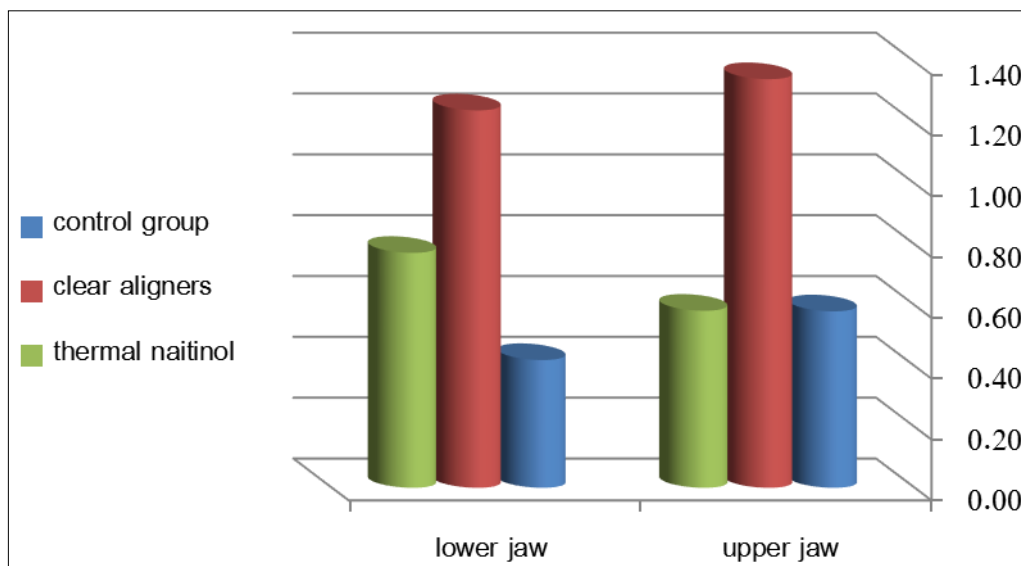


Fig 6: Figure shows the arithmetical averages of the amount of change in intra molar dental width among the three groups

Discussion

The natural occlusion forces are transmitted along the aligned teeth axes and dissipate without any damage to the components of the whole mastication system. The occlusion forces are transmitted through the teeth which suffer from malocclusion according to incorrect abnormal axes that can affect the work of the mastication system. One of the most important components of the mastication system is the temporomandibular joint which can be affected by these forces, so it was necessary to pay attention to correct the alignment and occlusion of teeth in order to maintain the safety of the mastication system and to achieve the best aesthetic results of the smile.

Since orthodontic treatment is one of the most effective things to make the smile bright and more attractive, it was necessary to search and investigate about the latest cosmetic techniques in the field of orthodontics. Clear aligners technique was one of the most important cosmetic techniques.

However, the studies that examined the treatment with clear aligners technique did not reach definite results on the effectiveness of this technique, where many of these studies were limited to the theoretical aspects of the technique and the results were predictive about the possibilities of treatment using this technique, while some moved to clinical research to confirm the expected theory results about this technique.

Hence, the importance of conducting clinical studies similar to our current study to investigate the accuracy of clear aligners technique in achieving the expected treatment results, comparing them with traditional methods of orthodontic treatment and investigating differences between these different techniques in terms of dental, skeletal, occlusal and aesthetic changes in different age groups and different malocclusion types, hence the idea of this research and its justifications.

This study has given us a lot of clinical results obtained from the three-dimensional casts and radiographic images. However, we limited in this article to the measurements that express the dimensions of the dental arch in the transversal direction only.

The most important of these results were:

The study of (intra canine dental width on the upper jaw and intra premolar dental width on the lower jaw) showed that both the clear aligners group and fixed orthodontic appliances using thermal naitinol archwires group showed significant statistical differences when compared with the control group (which treated with traditional fixed orthodontic appliances) at the P value ($p < 0.05$) and the confidence level $\alpha = 95$. And the average of both previous groups was larger than in the control group.

While the study of (intra canine dental width on the lower jaw and intra molar dental width on the upper jaw) showed that the clear aligners group showed significant statistical differences when compared with both the control group and the fixed orthodontic appliances using thermal naitinol archwires group at the P value ($p < 0.05$) and the confidence level $\alpha = 95\%$, and the average of clear aligners group was greater than in the remaining two groups.

The study of (intra premolar dental width on the upper jaw and intra molar dental width on the lower jaw) showed that the clear aligners group showed significant statistical differences when compared with the control group at the P value ($p < 0.05$) and the confidence level $\alpha = 95\%$, and the average of clear aligners group was greater than in the control group, while the other comparisons between the three groups did not show significant statistical differences.

The results of our study were consistent with the results of the studies of (Kassas W *et al.* Clements KM *et al.* Krieger E *et al.*) where the results of all studies showed the effectiveness of clear aligners technique in solving the problem of dental crowding and gave better results than the sample of fixed traditional orthodontic appliances whence treatment period, final occlusion, level of pain and acceptance of patients to the clear aligners technique [11, 12, 13].

The results of our study also concurred with the findings of Houle and his associates on the ability of clear aligners technique to expansion the dental arch and solve the problem of posterior dentoalveolar crossbites. The dental width of the arches was studied in the premolars and first molars level.

Both studies agreed on the superiority of clear aligners technique on traditional fixed orthodontic appliances in terms of their ability to change the dimensions of the dental arch in the posterior region of the dental arch^[15].

The results of our study differ with some studies such as the study of Baldwin and his assistants and Kravitz and his assistants, who denied the ability of the clear aligners technique to control the movement of dental tipping, especially for teeth with larger roots, while the results of our study confirmed the ability of clear aligners to control the movement of dental tipping by comparing the roots at end of treatment, the results were exactly the same between the treated group with clear aligners and the treated group with fixed orthodontic appliances. These results can be explained by the procedure we have done to increase the accuracy of desired movements by decreasing the maximum activate of aligners by division of these movements accurately for each aligner as well as application affixed attachments to the surfaces of the teeth^[8,9].

The contradictory results we have obtained from the analysis of these data on the possibility of controlling tip movements using clear aligners technique may be due to the difficulty of applying double force by this type of appliances. Changing the aligner geometry and applying adhesive attachments are essential to support root control. Thus, we need a good and correct design of the aligners to demonstrate the real effectiveness of the clear aligners technique by accomplishing the movement of crowns and roots along the dental arch^[10].

Conclusions

1. The measurement of (intra canine dental width on the upper jaw and intra premolar dental width on the lower jaw) in both the clear aligners group and fixed orthodontic appliances using thermal naitinol archwires group were larger with significant statistical differences when compared with the control group
2. The measurement of (intra canine dental width on the lower jaw and intra molar dental width on the upper jaw) in the clear aligners group were larger with significant statistical differences when compared with both the control group and the fixed orthodontic appliances using thermal naitinol archwires group.
3. The measurement of (intra premolar dental width on the upper jaw, intra molar dental width on the lower jaw) in the clear aligners group were larger with significant statistical differences when compared with the control group.

Suggestions

1. Conduct further studies to determine the potential of clear aligners technique in the treatment of different types of skeletal, dental and functional malocclusions.
2. Comparison of the clear aligners technique with other cosmetic techniques such as lingual orthodontic.
3. Conduct further studies of cases require teeth extraction and the application of technical adjustment to control the closing of extraction distances.
4. The use of attachments fixed to the dental surfaces in subsequent studies to facilitate the application of double wicks as well as the application of rubber between the two jaws in cases of class II and III malocclusion.

References

1. Srivastava R, Jyoti B, Kushwaha S, Shastri A. Sequential removal orthodontics: an alternative approach.

International Journal of Contemporary Medicine Surgery and Radiology. 2017; 2(1):32-36.

2. Tia C. How accurate is Invisalign? Are predicted tooth positions achieved? The University of Minnesota, 2017.
3. Vijayaalakshmi LG, Sumathifelicita A. Clear Aligners in Orthodontics. International Journal of Management, IT & Engineering. 2017; 7(7).
4. Brezniak N. The clear plastic appliance: A biomechanical point of view. Angle Orthod. 2008; 78:381-382.
5. Phan X, Ling PH. Clinical limitations of Invisalign. JCDA. 2007; 73:263-266.
6. Kesling HD. The philosophy of the tooth positioning appliance. Am J Orthod Dentofacial Orthop. 1945; 31:297-304.
7. Registered trademark of Align Technology, Inc, 881 Martin Ave, Santa Clara, CA 95050, 1999. www.aligntech.com
8. Ghafari JG. Centennial inventory: The changing face of orthodontics. Am J Orthod Dentofacial Orthop. 2015. 148:732-739.
9. Align Technology. Inc, 2018. <http://www.aligntech.com/>. Accessed 5 February
10. McLaughlin RP, Bennett JC. Evolution of treatment mechanics and contemporary appliance design in orthodontics: A 40-year perspective. Am J Orthod Dentofacial Orthop. 2015; 147:654-662.
11. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Forces and moments generated by removable thermoplastic aligners: Incisor torque, premolar derotation, and molar distalization. Am J Orthod Dentofacial Orthop. 2014; 145:728-736.
12. Proffit W. The timing of early treatment: An overview. Am J Orthod Dentofacial Orthop. 2006; 129:47-9.
13. Djeu G, Shelton C, Maganzini A. Outcome assessment of Clear aligners and traditional orthodontic treatment compared with the American Board of Orthodontics objective grading system. Am J Orthod Dentofacial Orthop. 2005; 128:292-298.
14. Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. How well does clear aligners work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. Am J Orthod Dentofacial Orthop. 2009; 135:27-35.
15. Baldwin DK, King G, Ramsay DS, Huang G, Bollen AM. Activation time and material stiffness of sequential removable orthodontic appliances. Part 3: premolar extraction patients. Am J Orthod Dentofacial Orthop. 2008; 133:837-45.
16. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Treatment outcome and efficacy of an aligner technique—regarding incisor torque, premolar derotation and molar distalization. BMC Oral Health 2014; 14:68.
17. Kassas W, Al-Jewair T, Preston CB, Tabbaa S. Assessment of Clear aligner treatment outcomes using the ABO Model Grading System. J World Fed Orthod. 2013; 2:e61-4.
18. Krieger E, Seiferth J, Marinello I, Jung BA, Wriedt S, Jacobs C *et al.* Invisalign_ treatment in the anterior region: were the predicted tooth movements achieved? J Orofac Orthop 2012; 73:365-76.
19. Clements KM, Bollen AM, Huang G, King G, Hujoel P, Ma T. Activation time and material stiffness of sequential removable orthodontic appliances. Part 2: dental improvements. Am J Orthod Dentofacial Orthop. 2003; 124:502-8.

20. Gu J, Tang JS, Skulski B, Fields HW Jr, Beck FM, Firestone AR. Evaluation of Clear aligner treatment effectiveness and efficiency compared with conventional fixed appliances using the Peer Assessment Rating index. *Am J Orthod Dentofac Orthop.* 2017; 151(2):259-66.
21. Houle JP, Piedade L, Todescan R Jr, Pinheiro FH. The predictability of transverse changes with Invisalign. *Angle Orthod.* 2017; 87(1):19-24.
22. Eissa O, Carlyle T, El-Bialy T. Evaluation of root length following treatment with clear aligners and two different fixed orthodontic appliances. A pilot study. *J Orthod Sci.* 2017; 7:11.
23. Jacobson A. *Radiographic Cephalometry: From Basics to Video imaging.* Chicago: Quintessence, 1995.