

THE RELIABILITY OF CLEAR ALIGNERS IN RESOLVING CROWDING

Mohammed A. Barashi^{1*}, Hesham A. Alhazmi¹

¹Preventive Department, Umm Al-Qura University, Makkah, Saudi Arabia

Corresponding author; Mohammed A. Barashi- mabarashi@uqu.edu.sa

The authors have contributed equally to this work.

ABSTRACT

Aim of the study Despite advancements in clear aligner therapy, there are still limitations regarding the predictability of tooth movements. Therefore, this study aims to evaluate how reliably clear aligners can address dental crowding. **Materials and methods** This retrospective study evaluated the orthodontic treatment outcomes using clear aligners in a sample of 60 patients. The study included healthy adults ages 18 to 60 who had non-extraction cases of crowding. Data were collected on their demographic details and clinical variables, with statistical analyses performed to compare initial and final crowding measurements and assess the need for orthodontic refinement. Chi-square tests and logistic regression were used to analyze the data and determine significant associations, if any. **Results** The predictability of clear aligners in resolving crowding was 65% (n = 39). Overall, the initial mean crowding of 4.13 mm (SD = 2.0) was reduced to a final mean crowding of 0.66 mm (SD=1.1). Patients who required an interproximal reduction (IPR) alone or an IPR with arch expansion were 2.38 times more likely to need refinement compared to those who had arch expansion only. This effect is statistically significant (p-value = <0.01). **Conclusions** Although the level of crowding had significantly decreased by the end of the study, the crowding was not fully resolved without additional refinements. Future studies should explore targeted interventions and have longer follow-up periods to achieve the complete resolution of crowding.

Key words: clear aligners, dental crowding, orthodontic refinement, interproximal reduction, arch expansion

INTRODUCTION

Dental crowding is the primary reason for individuals to seek an orthodontic treatment. The appropriate treatment approach for dental crowding depends on the severity of each case.¹ A systematic review from 2015 evaluated the comparison between early and late orthodontic treatment for tooth crowding involving the extraction of first premolars. It indicated that treatment could be performed through serial extractions of primary teeth, followed by the subsequent removal of the permanent first premolars.² In 2023, Stamenković et al. evaluated the treatment of severe crowding using self-ligating fixed orthodontic appliances. They found that severe crowding in young patients can be effectively addressed without the

need for extractions.³

Clear aligners created through computer-aided design/computer-aided manufacturing (CAD-CAM) systems are removable orthodontic devices designed to facilitate tooth movement.⁴ Improvements in biomechanics have enabled the treatment of more complex malocclusions, including class II, class III, and extraction cases.^{5, 6} Crowding can be addressed by using clear aligners for proclining the teeth, expanding the dental arch, performing an IPR, or extracting teeth in more severe cases. These strategies are similar to those used in traditional orthodontic treatments. However, achieving precise translational movements, particularly in cases involving extractions, tends to be less predictable with aligners.^{7, 8}

Discrepancies have been reported between the predicted tooth movements in ClinCheck and the actual movements achieved in extraction and non-extraction treatments.⁹ The type of movement needed determines how accurate the predicted tooth movement with clear aligners is; total predictability ranges from 55% to 72%.¹⁰

More specifically, Barashi et al. found a 75% accuracy rate in treating 55 patients with dental spacing using Invisalign.¹¹ Align Technology suggests that about 80% of the predicted tooth movement should be observable in ClinCheck.¹² Fiori et al. reported the predictability of resolving crowding with clear aligners, achieving 87% in the maxillary arch and 81% in the mandibular arch.¹³ Another study indicated that the accuracy of tooth rotation movement treated with clear aligners ranged from 75% to 78%.¹⁴

Our findings are consistent with a previous systematic study that assessed the clinical effectiveness of fixed appliance versus clear aligner treatment. According to the review, clear aligners were more successful in treating mild to moderate cases of malocclusion than severe cases.¹⁵ However, a study by Kravitz et al. comparing anticipated and actual tooth movements in 37 patients and 401 teeth reported an accuracy rate of only 41%.¹⁶ Nearly 50% of the patients in another study experienced a loss of incisor torque, and variations were noted in the predictability of movements among the different types of teeth.¹⁷

Despite the rise in the use of clear aligners, the data are still inadequate on the predictability of treating different malocclusions.¹⁸ A systematic review evaluated the effectiveness of clear aligner therapy in orthodontics. This reviews' findings suggest that clear aligners can

achieve clinically acceptable results similar to those of fixed appliances for the buccolingual positioning of the upper and lower incisors in cases of mild to moderate malocclusions. However, despite various improvements in clear aligner therapy, limitations remain concerning the predictability of tooth movements.¹⁹ Therefore, this study aims to assess the predictability of clear aligner in resolving dental crowding.

MATERIALS AND METHODS

This retrospective study was conducted on the accessible records of patients who had orthodontic treatments using Invisalign® clear aligners. Ethical approval was obtained from the College of Dentistry at Umm Al-Qura University Institutional Review Board Approval No. (HAPO-02-K-012-2024-06-2177). The data for this study were collected on July 30, 2024, and all information was fully anonymized prior to data collection, ensuring that no identifying information about individual participants was accessible during or after the study.

All samples were obtained from a private clinic in Makkah, Saudi Arabia. The sampling technique used in this study was convenience sampling, and the sample size was 60 patients. The determination of this sample size was based on several assumptions: an average lack of correction of 50%, a difference of 0.5 as reported in a previous study, a test power of 90%, an α -level of 0.05, and an assumed standard deviation of 1.²⁰

Healthy adult patients ages 18 to 60 years were recruited for this study based on specific criteria that included patients who underwent orthodontic treatment using clear aligner and non-extraction cases with crowding. Conversely, patients with spaces or those without any crowding were

excluded from the study.

The crowding before the orthodontic treatment was measured in millimetres (mm) and classified as mild (1–3 mm), moderate (3–6 mm), or severe (≥ 7 mm). Each case was classified as requiring an orthodontic refinement by adding more aligners to achieve the original treatment goals after completing the treatment or not.

Data for age and gender and clinical/orthodontic variables—length of treatment, arch type, type of treatment to resolve the crowding, and Angle classification—were collected. All orthodontic treatment was done by a single orthodontist. The dental models were uploaded to the ClinCheck Pro software (Align Technology Inc.). Pretreatment and predicted posttreatment dental models were exported from ClinCheck. The pretreatment amounts of crowding and the final achieved amounts of crowding after the treatment were measured separately for each arch.

The statistical analyses were performed using the Stata Version 18 (StataCorp, College Station, TX, USA). The counts and percentages for the demographic and clinical/orthodontic characteristics were conducted for all patients. Then, the counts and percentages, along with the chi-square tests, were conducted for the patients who needed orthodontic refinement or not.

We also measured the mean initial crowding and the final crowding measurements for all the variables. Paired t-tests were performed to assess the significance of the association between the crowding and the variables. An adjusted logistic regression analysis for age and gender was performed to assess the association between the need for refinement and the type of the treatment. Adjusted odds ratios (AORs) were reported and significance level of 5% ($\alpha = 0.05$) were

used.

RESULTS

The study included a total of 60 participants. Females made up the majority at 90.0% ($n=54$). Patients under 30 years of age constituted 61.7% ($n=37$) of the sample, while those 30 years and above made up 38.3% ($n=23$). The treatment duration was 6 months or less for 41.7% ($n=25$) and more than 6 months for 58.3% ($n=35$) of the participants. The majority of patients were treated in the lower arch (63.3%, $n=38$), while the upper arch was treated in 36.7% ($n=22$) of the cases. In terms of Angle classification, Class I patients comprised 70.0% ($n=42$) of the cases, and 53.3% ($n=32$) of participants had mild crowding. Regarding the type of treatment, 65.0% ($n=39$) received arch expansion only, while 35.0% ($n=21$) underwent IPR only or IPR with arch. Among the total, 35.0% ($n=21$) needed refinement and 65.0% ($n=39$) did not after orthodontic treatment. Regarding Angle classification, 28.57% ($n=12$) of Class I patients needed refinement, while 50.0% in both Class II ($n=6$) and Class III ($n=3$) categories needed refinement. For crowding severity, 21.88% ($n=7$) with mild crowding needed refinement, 42.11% ($n=8$) with moderate crowding needed refinement, and 66.7% ($n=6$) with severe crowding needed refinement. In terms of treatment type, 15.4% ($n=6$) of those receiving arch expansion only needed refinement, compared to 71.4% ($n=15$) of those receiving IPR alone or in combination with arch treatment. The variables of crowding severity and type of treatment received were found to be statistically significant ($p < 0.05$) in relation to the need for orthodontic refinement (Table 1).

Table 2 presents the mean initial and final crowding measured in millimetres, along

with the standard deviation (SD). Overall, the initial mean crowding of 4.13 mm (SD=2.0) was reduced to a final mean crowding of 0.66 mm (SD=1.1). Males had an initial mean crowding of 4.67 mm (SD=3.2), which reduced to a final mean crowding of 0.83 mm (SD=1.3). Females had an initial mean crowding of 4.07 mm (SD=1.9), which decreased to a final mean crowding of 0.64 mm (SD=1.0). Patients under 30 years of age had a smaller initial mean crowding of 3.78 mm (SD=1.9), compared to 4.68 mm (2 SD=.1) for those 30 years and above, and their final crowding were 0.55 mm (SD=1.0) and 0.83 mm (SD=1.2), respectively. Treatments completed in 6 months or less had an initial mean crowding of 3.6 mm (SD=1.4), which reduced to 0.56 mm (0.8), while longer treatments over 6 months had an initial mean crowding of 4.51 mm (SD=2.3), decreasing to 0.73 mm (SD=1.2). The upper arch had a smaller initial mean crowding of 3.68 mm (SD=2.0) compared to 4.39 mm (SD=2.0) in the lower arch, with final crowding of 0.64 mm (SD=1.0) and 0.67 mm (SD=1.1), respectively. Angle classification showed Class III malocclusions had the largest initial and final crowding, followed by Class II and Class I. Cases requiring refinement had greater initial and final crowding than those not needing refinement. The reduction from the initial crowding to the final crowding of the treatment was significant for all the variables, with a p-value less than 0.05.

Patients who required IPR alone or IPR with arch expansion were 2.38 times more likely to need refinement compared to those who had arch expansion only. This effect is statistically significant (p-value = <0.01). Additionally, there was no statistically significant association between the need of refinement and the severity of crowding (p-value > 0.05) (Table 3).

DISCUSSIONS

This retrospective study private clinic in Saudi Arabia aimed to investigate the clear aligners' accuracy in resolving crowding. Our results showed that the predictability of clear aligners in resolving crowding was 65% (n = 39). Furthermore, 68.18% (n = 15) of the cases in the upper arch didn't need refinement, and 63.16% (n = 24) of the cases in the lower arch didn't needed refinement. A previous study conducted by Fiori et al. reported that the predictability of resolving crowding with clear aligners was 81% in the mandibular arch and 87% in the maxillary arch. A possible explanation of why they achieved a higher predictability in their study is that they only included cooperative patients. They verified that the aligners were replaced at consistent intervals.¹³ In our study, the cooperation of the patients was only assessed if the patients completed their treatment regardless of their compliance in replacing the aligners at consistent intervals.

In our study, we found that the initial amount of crowding decreased significantly regardless of the ages of the patients, the length of their treatment, and the type of treatment strategies used to gain space, including arches being treated and malocclusion being classified. The mean of crowding initially decreased from 4.13mm to 0.66 mm at the end of a treatment. Despite the significant decrease in crowding, it was not resolved in all cases without the need for refinements. The mean of crowding in the upper arch was 3.6 mm, and the lower arch was 4.3 mm, reduced to 0.64 mm and 0.67 mm, respectively.

These findings agree with the previous study that found the amount of crowding decreased at the end of the first set of aligners. The crowding was statistically significantly reduced, but the crowding was

not completely resolved without refinements. They reported the mean of crowding in the upper arch is 7.2mm and 8.1 mm in the lower arch. At the end of the first stage, some crowding still occurred, with 2.8 mm in the upper arch and 2.6 mm in the lower arch.¹³ The treatment outcome confirmed that clear aligner therapy effectively resolves crowding, but unfortunately, some cases will need extra aligners to achieve the original treatment goals. Moreover, due to our study's relatively small sample size of males and class III malocclusions, the difference between males and females and between angel classifications should be taken cautiously.

Also, our research results showed the final crowding for cases that needed refinement was significantly higher (P value = <0.01) than the cases that didn't need refinement, 1.83 and 0.03, respectively. Our findings are consistent with a previous systematic study that assessed the clinical effectiveness of fixed appliance versus clear aligner treatment. According to the review, clear aligners were more successful in treating mild to moderate cases of malocclusion than severe cases.²¹ This finding suggested that cases with moderate to severe crowding were more likely to fail to reach treatment goals without refinements, so monitoring these cases throughout the treatment is important.

Our results showed that the type of treatment choice could affect the efficacy of the clear aligner in resolving crowding. IPR only or IPR with an arch expansion showed less predictable results than an arch expansion. Patients who were treated with IPR alone or IPR with an arch expansion were 2.38 times more likely to need refinement compared to those who had arch expansion only.

A study found that IPR was the least predictable method for resolve crowding. Their data showed the accuracy of IPR at 49% in the upper arch and 42% in the lower one.¹³ This result could be due to the predictability of IPR being a complex issue. The precise amount of enamel needed to be removed depends on several factors, some of which are connected to the tooth's characteristics like enamel hardness, crown anatomy, or tooth or position. Others are related to the operator's experience, the IPR method, and the amount of pressure applied during the process.

Our study has some limitations. The primary research limitation is that the efficacy of clear aligner therapy is depends heavily on the compliance of patients. This underscores the significant role that patients play in the success of their treatment. Numerous factors could have impacted the findings' statistical power and generalizability. To begin with, the study's sample size was relatively small. Women made up the majority of participants (90%; N = 54). Then convenience sampling was the method used for the sample. Finally, a single center was used to recruit each patient. As such, care should be taken while interpreting the data. Our research also has a number of strengths. Uniformity in the administration of the treatment protocol was ensured by the fact that only one orthodontist performed the therapy examined in this study. A number of clinical and orthodontic variables as well as demographic studies were carried out, enabling a more thorough analysis. Future prospective studies are therefore needed to provide more data about the predictability of clear aligners in resolving crowding. More studies are necessary to clarify on the efficacy of treatment strategies in resolving crowding with clear aligners.

Table 1. Demographic and Orthodontic Characteristics by the Need of Orthodontic Refinement

Demographic /Orthodontic variables	Total	Need refinement		P-value ^a
	n ^β =60	No, n= 39 (65.0%)	Yes, n= 21 (35.0%)	
	n (%)	n (%)	n (%)	
Gender				
Male	6 (10.0%)	4 (66.67%)	2 (33.33%)	0.928
Female	54 (90.0%)	35 (64.81%)	19 (35.19%)	
Age				
<30 years	37 (61.7%)	24 (64.86%)	13 (35.14%)	0.978
≥30 years	23 (38.3%)	15 (65.22%)	8 (34.78%)	
Length of treatment				
6 months or less	25 (41.7%)	15 (60.00%)	10 (40.00%)	0.493
More than 6 months	35 (58.3%)	24 (68.57%)	11 (31.43%)	
Arch				
Upper	22(36.7%)	15 (68.18%)	7 (31.82%)	0.694
Lower	38 (63.3%)	24 (63.16%)	14 (36.84%)	
Angel classification				
Class I	42 (70.0%)	30 (71.43%)	12 (28.57%)	0.280
Class II	12 (20.0%)	6 (50.00%)	6 (50.00%)	
Class III	6 (10.0%)	3 (50.00%)	3 (50.00%)	

Crowding				
Mild	32 (53.3%)	25 (78.12%)	7 (21.88%)	0.033*
Moderate	19 (31.7%)	11 (57.89%)	8 (42.11%)	
Severe	9 (15.0%)	3 (33.33%)	6 (66.67%)	
Type of treatment				
Arch expansion only	39 (65.0%)	33 (84.62%)	6 (15.38%)	<0.01*
IPR ^δ only or IPR with arch	21 (35.0%)	6 (28.57%)	15 (71.43%)	

^α Statistical test= Chi Square tests

^β n= number of patients

^δ IPR= interproximal reduction

* Less than 0.05

Table 2. Demographic and Orthodontic Characteristics by the Initial and Final Crowding

Demographic /Orthodontic variables	Initial crowding, mean (SD) ^α	Final crowding, mean (SD) ^β	P-value
Total	4.13 (2.0)	0.66 (1.1)	
Gender			
Male	4.67 (3.2)	0.83 (1.3)	<0.01*
Female	4.07 (1.9)	0.64 (1.0)	<0.01*
Age			
<30 years	3.78 (1.9)	0.55 (1.0)	<0.01*
≥30 years	4.68 (2.1)	0.83 (1.2)	<0.01*
Length of treatment			
6 months or less	3.6 (1.4)	0.56 (0.8)	<0.01*
More than 6 months	4.51 (2.3)	0.73 (1.2)	<0.01*

Arch			
Upper	3.68 (2.0)	0.64 (1.0)	<0.01*
Lower	4.39 (2.0)	0.67 (1.1)	<0.01*
Angel classification			
Class I	3.97 (2.0)	0.43 (0.8)	<0.01*
Class II	4.33 (1.8)	1.17 (1.3)	<0.01*
Class III	4.83 (2.9)	1.25 (1.8)	0.0256*
Need refinement			
No	3.51 (1.6)	0.03 (0.2)	<0.01*
Yes	5.29 (2.2)	1.83 (1.0)	<0.01*
Type of treatment			
Arch expansion only	3.37 (1.5)	0.28 (0.7)	<0.01*
IPR ^δ only or IPR with arch	5.53 (2.1)	1.36 (1.2)	<0.01*

^α SD= Standard deviation^β Statistical test= Paired t-tests^δ IPR= interproximal reduction

* Less than 0.05

Table 3. Logistic Regression Analysis of the Association Between the Need of Orthodontic Refinement and the Type of Treatment Provided

Variables	Reference group	Adjusted odds ratio ^α	P-value
IPR ^β only or IPR with arch expansion	Arch expansion only	2.38	0.001*
Moderate crowding	Mild crowding	0.52	0.478
Severe crowding	Mild crowding	0.83	0.359

CONCLUSIONS

Although the level of crowding significantly decreased by the end of the study, it was not fully resolved without additional refinements. Future studies need to focus on

exploring targeted interventions that include various treatments to address any remaining crowding. Additionally, incorporating a longer follow-up period could provide insights into the long-term effectiveness of these

interventions and their impact on crowding resolution.

REFERENCES

1. Proffit W, Fields HW. Contemporary Orthodontics. 3rd ed. St Louis: Mosby; 2000, 9–13,141–142, 161–166, 248–252.
2. Filho HL, Maia LH, Lau TC, de Souza MM, Maia LC. Early vs late orthodontic treatment of tooth crowding by first premolar extraction: A systematic review. *The Angle Orthodontist*. 2015 May 1;85(3):510-7.
3. Stamenković Z, Nedeljković N, Mirjanić V, Stojić V, Marinković N, Arsić I, Marković J, Krčić V. Treatment of severe crowding with self-ligating fixed orthodontic appliance. *Contemporary materials*. 2023 Dec 30;14(2).
4. Weir T. Clear aligners in orthodontic treatment. *Australian dental journal*. 2017 Mar;62:58-62.
5. D'Antò V, Valletta R, De Simone V, Pisano M, Martina S. Clear aligners treatment of class III subdivision with an extraction of a lower bicuspid. *International Journal of Environmental Research and Public Health*. 2023 Feb 17;20(4):3550.
6. Rongo R, Dianišková S, Spiezia A, Bucci R, Michelotti A, D'Antò V. Class II malocclusion in adult patients: What are the effects of the intermaxillary elastics with clear aligners? A retrospective single center one-group longitudinal study. *Journal of Clinical Medicine*. 2022 Dec 9;11(24):7333.
7. Buschang PH, Ross M, Shaw SG, Crosby D, Campbell PM. Predicted and actual end-of-treatment occlusion produced with aligner therapy. *The Angle Orthodontist*. 2015 Aug 1;85(5):723-7.
8. Robertson L, Kaur H, Fagundes NC, Romanyk D, Major P, Flores Mir C. Effectiveness of clear aligner therapy for orthodontic treatment: A systematic review. *Orthodontics & craniofacial research*. 2020 May;23(2):133-42.
9. Dai FF, Xu TM, Shu G. Comparison of achieved and predicted tooth movement of maxillary first molars and central incisors: first premolar extraction treatment with Invisalign. *The Angle Orthodontist*. 2019 Sep 1;89(5):679-87.
10. Galan-Lopez L, Barcia-Gonzalez J, Plasencia E. A systematic review of the accuracy and efficiency of dental movements with Invisalign®. *The korean journal of orthodontics*. 2019 May;49(3):140-9.
11. Barashi MA, Habis RM, Alhazmi HA. Predictability of Orthodontic Space Closure Using Invisalign Clear Aligners: A Retrospective Study. *Cureus*. 2024 Mar;16(3).
12. Houle JP, Piedade L, Todescan Jr R, Pinheiro FH. The predictability of transverse changes with Invisalign. *The Angle Orthodontist*. 2017 Jan 1;87(1):19-24.
13. Fiori A, Minervini G, Nucci L, d'Apuzzo F, Perillo L, Grassia V. Predictability of crowding resolution in clear aligner treatment. *Progress in Orthodontics*. 2022 Nov 28;23(1):43.
14. D'Antò V, Rongo R, Casaburo SD, Martina S, Petrucci P, Keraj K, Valletta R. Predictability of tooth rotations in patients treated with clear aligners. *Scientific Reports*. 2024 May 18;14(1):11348.
15. Alswajy W, Baeshen H, Al-Turki G, Alsulaimani F. The Reliability of ClinCheck® Accuracy before and after Invisalign® Treatment—a multicenter retrospective study. *Applied Sciences*. 2023 Apr 7;13(8):4670.
16. Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2009 Jan 1;135(1):27-35.

17. 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 Dec;14:1-7.
18. 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 Dec;14:1-7.
19. Robertson L, Kaur H, Fagundes NC, Romanyk D, Major P, Flores Mir C. Effectiveness of clear aligner therapy for orthodontic treatment: A systematic review. *Orthodontics & craniofacial research*. 2020 May;23(2):133-42.
20. Haouili N, Kravitz ND, Vaid NR, Ferguson DJ, Makki L. Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2020 Sep 1;158(3):420-5.
21. Yassir YA, Nabbat SA, McIntyre GT, Bearn DR. Clinical effectiveness of clear aligner treatment compared to fixed appliance treatment: an overview of systematic reviews. *Clinical oral investigations*. 2022 Mar;26(3):2353-70.