Educational Administration: Theory and Practice
2024, 30(4), 7494-7502
ISSN: 2148-2403
https://kuey.net/

Research Article

"Evaluation of Difference Between Predicted and Achieved Outcome in Maxillary Dentoalveolar Expansion with Clear Aligner Therapy- A Systematic Review"

Dr Vishwa Shah[1*], Dr Santosh Kumar Goje[2]

[1*]BDS, Post graduate student (MDS resident), Department of Orthodontics and Dentofacial Orthopaedics, KMSDCH, Vadodara, Gujarat, India Department of Orthodontics and Dentofacial Orthopaedics, Vadodara, Gujarat, India K.M. Shah Dental College and Hospital, pin-391760, vishwafshah@gmail.com
[2]BDS, MDS, Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, KMSDCH, Vadodara, Gujarat, India Department of Orthodontics and Dentofacial Orthopaedics, Vadodara, Gujarat, India K.M. Shah Dental College and Hospital, pin-391760, santoshgoje@gmail.com

Citation: Dr Vishwa Shah et al. (2024), "Evaluation of Difference Between Predicted and Achieved Outcome in Maxillary Dentoalveolar Expansion with Clear Aligner Therapy- A Systematic Review", *Educational Administration: Theory And Practice*, *30(4),* 7494-7502, Doi: 10.53555/kuey.v30i4.2596

ARTICLE INFO

ABSTRACT

Aim: The aim of this systematic review is to evaluate the difference between predicted and achieved outcome in maxillary dentoalveolar expansion with Clear aligner therapy. Material and methods: A search of the keywords "Clear Aligner Therapy, Maxillary Expansion, Predictability OR Efficacy, Expansion with clear aligner therapy, Expansion in adults, Clear Aligners, Predictability was conducted on search engines like PubMed, Google Scholar, and Cochrane Library from the year 1997-2023. Inclusion criteria for this systematic review included: all Randomized clinical trials (RCTs) and prospective and retrospective studies with concurrent untreated control groups (CCTs). Article in English language, only human clinical trial, Articles regarding the expansion using the clear aligner therapy along with its efficacy and predictability by the respective software in adult patients, published from the year 1997-2023. Statistical analysis: The following characteristics were evaluated: study design, sample size, sample description, error analysis, and statistical analysis. The quantified data on Efficacy of the treatment and Predictability of the software used, was extracted from the selected articles. Risk of bias (whether mentioned or not) was checked and quality assessments of studies were performed. Results: Ten studies were reviewed in this article. From the included articles, the following data were extracted independently: author names, year of publication, type of studies, sample size, mean age of subjects, Efficacy and Predictability in inter canine, inter 1st premolar, inter 2nd premolar, inter 1st molar and inter 2nd molar regions. Maximum efficacy of clear aligner treatment was found in the 1st premolar region with average of 82.13% and minimum in the 1st and 2nd molar region with an average of 66.8% and 53.3% respectively. Maximum loss of predictability in the treatment i.e., 33.2% and 46.7% was found in 1st and 2nd molar region respectively. Conclusion: Based on the results it is recommended to have careful planning with overcorrection and other auxiliary methods of expansion which may help reduce the rate of midcourse corrections and refinements, especially in the posterior region of the maxilla.

Keywords: Clear Aligner Therapy, Maxillary Expansion, Predictability OR Efficacy, Expansion with clear aligner therapy, Expansion in adults, Clear Aligners, Predictability

1. INTRODUCTION

In the transverse plane, occlusion is considered correct when the palatal cusps in the upper posterior regions occlude into the fossae of the lower posterior teeth. When the vestibular cusps in upper posterior regions occlude into the fossae of the lower posterior teeth, this produces the malocclusion known as posterior crossbite. This type of malocclusion may be of skeletal origin or dental origin. Skeletal malocclusion is when

the dentoalveolar processes are correctly positioned in relation to the bone base but the base presents either maxillary skeletal hypoplasia or mandibular skeletal hyperplasia or both. Dental malocclusion is when, the bone base will present a correct transversal proportion but irregular dentoalveolar processes. Epidemiological research places the prevalence of crossbite between 1% and 21% [1,2] but variations may occur based on country, social class, age of the subjects. Treatment of the skeletal transverse malocclusion is skeletal expansion and for dental transverse malocclusion is dentoalveolar expansion.

There is a huge shift of treatment modality from fixed conventional brackets to Clear Aligner Therapy in the recent years, it is an improvised form of Tooth Positioner introduced in 1946 by Dr. Harold Kesling. Patients are given a set of aligners, to be changed every other week, and worn 22 hours a day. Tooth movement and retention of aligners are allowed by composite resin attachments bonded to the buccal surfaces. A study showed that more adult patients are turning to aligner treatment because they consider it more aesthetic than conventional brackets and more comfortable than lingual orthodontics[3]. Clear aligners facilitate oral hygiene, cause less pain as compared to fixed orthodontic appliances, reduce the number and duration of appointments, and require less emergency visits. [4,5]

Literature shows that the reliability of orthodontic tooth movement (OTM) with aligners does not seem encouraging. Several papers have demonstrated that what is virtually planned is not what is clinically achievable. Even if some limitations in the appliance system remain, it should be considered that clear aligner orthodontics techniques are customized not only for the patients but for orthodontists too. Therefore, virtual treatment plan design, in terms of attachments design and placement, OTM staging and aligner deformation overengineering, or in other words aligners biomechanics knowledge, plays a crucial role in defining the quality of the orthodontic treatment with aligners.

Arch expansion is possible with Invisalign and may be required to improve the esthetics of the smile by broadening the dental arches or as a mechanism to create space for resolution of crowding.[6] It can also be used as a way of correcting dentoalveolar posterior crossbites. Boyd and Vlaskalic[7] reported that buccal expansion in the range of 2-4mm can be achieved to alleviate crowding or to modify the arch form. Ali et al[8] in 2012, stated that dentoalveolar expansion limited to 2-3mm per quadrant is possible with Invisalign and can be an alternative to interproximal reduction. Malik et al[9] in 2013 reported that expansion is an indication to use Invisalign when having to resolve 1–5 mm of crowding. In the same article, dental expansion using Invisalign was also recommended for blocked out teeth. There are limited data on the amount of discrepancy between predicted and actual achieved movements with Invisalign.[10] In a prospective clinical study by Kravitz et al.[11] in 2009, the mean accuracy of tooth movement in the anterior region was found to be 41% Invisalign aligners have found prediction accuracies in the 70%-80% range. Houle et al[12] found that the mean accuracy of 72.8% in the maxillary arch and 87.7% in the mandibular arch. Solano-Mendoza et al[13] concluded that expansion was not predictable as significant differences were found between predicted and achieved expansion for all teeth (canines to first molars), but did not provide a quantitative figure for accuracy. Zhou and Guo[14] again used linear measurements from cusp tips to measure expansion and found lower but comparable accuracies to Houle et al.[12] More recently, Haouili et al[15] superimposed pretreatment, predicted, and posttreatment models with a best-fit algorithm and found an overall 50% accuracy of all tooth movements (mesial-distal and buccal-lingual crown tip, rotation, extrusion, intrusion, and rotation), with buccal tooth movements from the canine to the second molar ranging from 35%-70%. Knowing the accuracy of the software at predicting changes could help the practitioner to anticipate the need of overcorrection, thereby reducing refinements, midcourse corrections, and treatment time with clear aligners. Hence, objective of the present systematic review is to determine the efficacy of clear aligner therapy in achieving maxillary expansion and predictability of the Clear aligner therapy in achieving the same.

The following questions will be answered in this systematic review: 1. How effective is Clear aligner therapy in achieving maxillary dentoalveolar expansion? 2. Is the software predicted maxillary arch expansion comparable to actual post treatment maxillary expansion in patients treated with Clear Aligner Therapy? 3. During maxillary arch expansion with Clear Aligner Therapy, does expansion occur through bodily movement or tipping movement of posterior teeth.

2. MATERIALS AND METHODS

TABLE 1: Eligibility criteria for study selection	
Type of Studies	Clinical studies referring to efficacssy and predictability of maxillary expansion with Invisalign. Eligible studies were observational designs, retrospective or prospective cohorts, and cross-sectional or case-control studies, Randomized Controlled and Un-Controlled Trials, all non-randomized controlled and un-controlled trials, articles published till the year 2023.
Participants	Studies involving adult patients undergoing expansion with Clear Aligner Therapy with (1) narrow / constricted maxillary arches (2) completion of non-extraction Clear Aligner treatment

	(3) planned expansion across at least 1 maxillary posterior tooth pair. (4) growth completed before treatment. (5) pretreatment and posttreatment models were available were included No gender restrictions
Intervention	Maxillary arch expansion with Clear Aligner Threrapy (CAT).
Outcome measures	Quantitative evaluation of the difference between predicted and achieved outcomes in patients undergoing maxillary dentoalveolar expansion under the following terms: Predictability- software predicted expansion vs Actual expansion achieved Efficacy- Pre-treatment expansion vs post-treatment expansion.

This systematic review was based on the PRISMA guidelines and the main objective was defined with PICO format[16,17].

TABLE 2	
PICO FORMAT	
Population	Patients requiring maxillary expansion.
Intervention	Expansion by Clear Aligner Therapy.
Comparision	Predictability- Software predicted expansion vs actual expansion achieved. Efficacy- Pre treatment expansion vs Post treatment expansion achieved.
Outcome	Quantitative evaluation of the difference between predicted and achieved outcomes in terms of maxillary dentoalveolar expansion

A search of the keywords (Maxillary expansion OR Palatal expansion) AND (Clear Aligner Therapy OR Invisalign), (Predictability OR efficacy) AND (Expansion OR palatal expansion OR maxillary expansion) AND (Clear aligners OR Invisalign), (Efficacy OR Predictabilty) AND (Invisalign OR clear aligner therapy) was conducted on search engines like PubMed, Google Scholar and Cochrane Library till the year 2023. Initially the articles were selected on the basis of title and abstracts, then the selected Sarticles were thoroughly analyzed and inclusion & exclusion criteria were applied for the final selection of articles. Inclusion criteria for this systematic review included: all Randomized Controlled and Un-Controlled Trials, all non-randomized controlled and un-controlled trials, prospective and retrospective studies, CBCT studies, articles published from till the year 2023, articles published in English language, articles with full text available. Case reports, case series, systematic reviews, in-vitro studies, books and documents, expert opinions and reviews. The selection process was independently conducted by 2 researchers, and the results were compared to identify discrepancies and reduce inter-personnel errors. The articles with unsatisfactory abstracts, were completely read and analyzed. Inter-examiner conflicts were resolved by discussion of each article to reach a consensus regarding all selection criteria. The quality of each included article was scored by using an adapted version of 3 methods previously used by Fudalej and Antoszewska[18], Cozza et al[19] and Chen et al[20]. The following characteristics were evaluated: study design, sample size, sample description, error analysis and statistical analysis. The data from the selected article was retrived to analyse efficacy and predictability.

3. RESULTS

After a thorough search of electronic databases, 661 studies were retrieved from PubMed, 874 from Science Direct, and 6590 from Google Scholar. After application of the initial inclusion and exclusion criteria and elimination of studies indexed in more than 1 database, 8125 were retrieved. The full texts were accessed, studies irrelevant to this systematic review were excluded. Ultimately, 10 articles that fulfilled all inclusion and exclusion criteria were included in this systematic review (Fig.1)

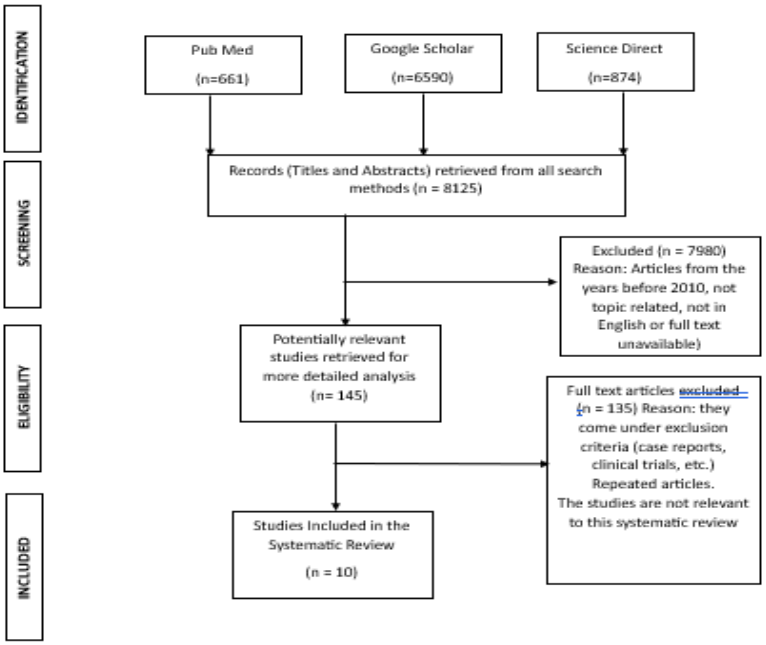

FIG 1: PRISMA Flow Diagram

From the remaining articles, we independently extracted the following data: Author names, year of publication, presence or absence of crossbite in the sample of the study, Type of Expansion Method; change in inter canine width, inter 1st premolar width, inter 2nd premolar width, inter 1st molar width, inter 2nd molar width, software predictability measured in percentage. Predictability and efficacy of Expansion of maxillary arch with clear aligner therapy was evaluated using pre-treatment, predicted, post treatment digital models.

TABLE 3

SR.NO	AUTHOR	YEAR OF STUDY	SAMPLE	TYPE OF STUDY	EFFICACY	PREDICTABILITY	AGE
1	Gabriella Galluccio[21]	March 2023	28	Prospective	Given in mm	Given in mm	17- 25 years
2	Tien et al[22]	January 2023	57	Retrospective	Given in mm	Given in terms of percentage (%)	20 years
3	Santucci et al[23]	February 2023	32	Retrospective	Given in terms of mean and SD (calculated on CBCT)	Given in terms of mean and SD	29.25 ± 9.75 years
4	D'Antò et al[24]	February 2023	30	Prospective	Given in terms of mean and SD	Given in terms of mean and SD	27 ± 6.1 years
5	Ana Nogal-Coloma et al[25]	February 2023	46	Prospective	Given in terms of percentage	Given in terms of percentage	20-60 years
6	Lione et al[26]	February 2021	28	Prospective	Given in terms of mean and SD	Given in terms of mean and SD	31.9 years
7	Maria-Luisa Vidal-Bernárdez et al[27]	March 2021	64	Retrospective	Given in terms of percentage	Given in terms of percentage	>16 years
8	Ignacio Morales-Burruezo et al[28]	December 2020	114	Retrospective	Given in terms of percentage	Given in terms of percentage	18-60 years
9	Ning Zhou et al[14]	August 2019	20	Prospective	Given in terms of percentage	Given in terms of percentage	20-45 years
10	Houle et al[12]	June 2016	64	Retrospective	Not measured	Given in terms of mean	31.2 years

Efficacy and loss in predictability wherever mentioned in percentage was directly extracted. Studies where the data was not mentioned in the form of percentage was calculated using the following formula. Efficacy= (Actual outcome/ Predicted outcome) X 100, where Actual outcome is difference between actual post treatment measurement and pre-treatment measurement; and predicted outcome is the difference between software obtained post treatment measurement and pre-treatment measurement.

The following table shows the calculated value,

TABLE 4 : EFFICACY

	Inter canine	Inter 1 ST premolar	Inter 2 nd premolar	Inter 1 st molar	Inter 2 nd molar
Gabriella Galluccio[21]	81.99%	93.53%	79.43%	70.55%	-
Tien et al[22]	72.78%	78.9%	81.1%	63.5%	41.4%
Santucci et al[23]	-	76.12%	68.93%	43.77%	-
D'Antò et al[24]	82.79 ± 12.25%	78.36 ± 10%	73.84 ± 15.64%	60.59± 15.55%	-
Ana NogalColoma et al[25]	74.29%	81%	84.98%	74.81%	-
Lione et al[26]	57%	89%	90%	57%	-
Maria-Luisa Vidal-Bernárdez et al[27]	77.14%	83.33%	99.04%	74.3%	-
Ignacio Morales-Burruezo et al[28]	74.8%	80.3%	81.0%	79.1%	65.2%
Ning Zhou et al[14]	79.75%	76.10%	73.27%	68.31%	-
Houle et al[12]	88.7%	84.7%	81.7%	76.6%	-
AVERAGE	76.51%	82.13%	79.36%	66.8%	53.3%

TABLE 5 : LOSS IN PREDICTABILITY

	Inter canine	Inter 1ST premolar	Inter 2nd premolar	Inter 1st molar	Inter 2nd molar
Gabriella Galluccio[21]	18.01%	6.47%	20.57%	29.45%	-
Tien et al[22]	27.22%	21.1%	18.9%	36.5%	58.6%
Santucci et al[23]	-	23.88%	31.07%	56.23%	-
D'Antò et al[24]	17.21%	21.64%	26.16%	39.41%	-
Ana Nogal-Coloma et al[25]	25.71%	19%	15.02%	25.19%	-
Lione et al[26]	43%	11%	10%	43%	
Maria-Luisa VidalBernárdez et al[27]	22.86%	16.67%	1%	25.7%	-
Ignacio Morales-Burruezo et al[28]	25.2%	19.7%	19%	20.9%	-
Ning Zhou et al[14]	20.25%	23.9%	26.73%	31.69%	34.8%
Houle et al[12]	11.3%	15.3%	18.3%	23.4%	-
AVERAGE	23.49%	17.87%	20.64%	33.2%	46.7%

TABLE 6: QUALITY ASSESSMENT OF THE SELECTED ARTICLES

Sr no	Author	Sample design (0-3)	Sample size (0-1)	Sample description (0-2)	Error analysis(0-1)	Statistical analysis (0-2)	Quality score (0-9)	Judges quality standard
1.	Gabriella Galluccio 2023[21]	1	1	1	0	2	5	Medium
2.	Tien et al 2023[22]	0	1	1	0	2	4	Medium
3.	Santucci et al	0	1	1	0	2	4	Medium

	2023[23]							
4.	D'Antò et al 2023[24]	1	1	1	0	2	5	Medium
5.	Ana Nogal-Coloma et al 2023[25]	1	1	1	0	2	5	Medium
6.	Lione et al 2021[26]	1	1	1	0	2	5	Medium
7.	Maria-Luisa Vidal-Bernárdez et al 2021[27]	0	1	0	0	2	3	Low
8	Ignacio Morales-Burruezo et al 2020[28]	0	1	1	0	2	4	Medium
9	Ning Zhou et al[15]	1	1	1	0	2	5	Medium
10	Houle et al[2]	0	1	1	0	2	4	Medium

After quality analysis, articles were classified as 9 as medium quality and 1 as low quality (Table VI).
It was observed that the efficiency of clear aligner therapy to cause maxillary expansion decreases from anterior region to posterior region.
The average efficacy of clear aligner therapy in different tooth region and the loss of thepredicted expansion in the post treatment outcome is calculated in the table above.
It is observed that most amount of expansion has occurred in the 1st premolar region followedby 2nd premolar region, canine region, 1st molar region and the least amount of expansion is seen in the 2ndmolar region. Loss in the amount of predictability increases from anterior to posterior region.Most of the studies conclude that the type of expansion occurring is dentoalveolar expansion.
Few studies have measured the amount of expansion at the gingival level of canine, 1st premolars, 2nd premolars, 1st molars, 2nd molars and molar inclinations to calculate the amount of tippingas well as the bodily translation. But, there isn't enough evidence available to compare the given studies and quantify the amount of bodily movement or the amount of tipping of the teeth.

According to each criterion for quality analysis, the following results were obtained:
Study design: Only 5 studies were prospective clinical trial and rest wereretrospective studies described in detail.
Sample size: The authors of all the 10 studies performed sample-sizecalculation or had sample sizes larger than or equal to 15 patients.
Selection description: 9 studies gave proper sample description includingage, requirement of maxillary arch expansion etc.
Error analysis: none of the studies performed and described the methoderror results.
Statistical analysis: the authors of all 10 studies performed detailed analysis.

4. DISCUSSION

Although the Clear aligner methodology has been successfully improved in recent years, knowledge related to the appliance is significantly limited in terms of scientific evidence. Hence, the purpose of this investigation was to assess the expansion movement pattern of CAT when planning transverse changes in order to provide a suitable protocol for achieving predictable and stable results. An adult population was chosen to participate in this study to avoid bias due to normal transverse growth of the jaws. Traditional dentoalveolar expansion devices mainly result in expansion of the upper arch by means of an increase in posterior buccal tipping, with subsequent bone modeling, obtained through broadened arches or repeated activations of a quadhelix appliance. In the digital set-up for transverse expansion with CAT, a combination of both dental tipping and bodily translation of posterior teeth is usually planned, and the predicted values tend to be variable depending on the teeth involved.

The purpose of this systematic review is to evaluate the difference between predicted and achieved outcome in maxillary dentoalveolar expansion with Clear aligner therapy on the basis of scientific evidences from the existing literature on all the peer-reviewed orthodontic journals according to the Cochrane collaboration principles.

In a systematic review, it is important to evaluate the quality of the articles and allow inclusion of better quality articles in the systematic review to decrease the heterogeneity among them, with the goal of presenting more reliable data. In health field investigations, which involve patient treatments, significant degrees of clinical, methodological, and statistical heterogeneity are expected because of the nature of these studies and the different variables involved, and the entire systematic review project must address this issue.[29]

A retrospective study conducted by Ignacio Morales-Burruezo et al[28] with 114 adults was conducted which assessed the predictability of the system's software by comparing planned measurements (width of canines, premolars and molars rotations and inclinations) with the real measurements achieved at the end of the first treatment phase. For all widths, virtual planning obtained prognoses of greater expansion than actually achieved. A mean of 0.63 mm more expansion at the canine level, 0.77 mm at first premolar, 0.81mm at second premolar, 0.69 mm at first molar, and 0.25 mm at second molar. Predictability was reasonable for expansion movement. Overcorrection was adviced at the virtual planning stage in order to obtain the expected outcomes. Another retrospective study conducted by B. Solano-Mendoza et al[13] in 116 adults was the first human in vivo study to quantify the predictability of expansion. Pre treatment and post treatment widths from canineto 1 st molar at cuspid as well as at gingival level, molar rotation, molar inclination, arch depth were measured on 3D model and on the planning software. Results showed nonsignificant differences between the 3D model and planning software on pre treatment measurements for all variables except first molar cuspid width and arch depth. Statistically significant differences were found for canine, 1st premolar, 2 nd premolar 1st molar level when the 3D model and software measurements were compared at post treatment. The study finally concluded that differences between the 3D model and planning software at post treatment showed that planned expansion at the end of treatment is not predictable. But Studies by Solano Mendoza et al[13] and Riede et al[29] were excluded as the mentioned data was not appropriate for conversion into percentage format. Similar retrospective study was conducted by Maria-Luisa Vidal-Bernárdez et al[27] , with 64 upper and 51 lower arches treated with Smart Track material of Invisalign system. Canine, premolar and molar width was measured at the gingival and cuspid level of both arches, along with the inclination of the upper first molar. It was found that predictability, around 98-100% was achieved at the coronal level and between 85-90% at the gingival level in the upper arch and expansion in the lower arch is more predictable at the gingival level than in the upper arch. A prospective study by Gabriella Galluccio et al[21] showed an average accuracy of efficacy of 70.88%. The differences in predictability between the various vestibular measurements (intercanine, inter-premolar, and intermolar) were not statistically significant, while they were for gingival measurements and the overall accuracy of the expansion treatment was 70%, regardless of tooth type. Ana Nogal-Coloma et al[25] divided 46 patients into, 15 with unilateral, 15 bilateral, and 16 single-tooth crossbite groups. In all crossbite groups, expansion was largest at the second premolar level (unilateral: 2.54 mm; bilateral:,4.86 mm; single-tooth: 3.41 mm) and smallest at the canine level. Expansion predictability was 90% at the first premolar level in the single tooth crossbite group, 86% at the second premolar level in the bilateral crossbite group, and 79% at the second premolar level in the unilateral crossbite group the study concluded that dentoalveolar expansion using differential anchorage techniques with clear aligners is highly predictable, although the treatment plan should consider overcorrection of the expansion movement to achieve the planned outcome. Prospective study by Vincenzo D'Antò et al[24] concluded that total accuracy of 64% for the lower arch, 67% at the cusp level, and 59% at the gingival level, with a total accuracy of 67% for the upper arch, 71% at the cusp level, and 60% at the gingival level was found. The mean accuracy for molar inclination was 40%. Average expansion was greater at cusps of canines than for premolars, and it was lowest for molars. The expansion achieved with aligners is mainly due to the tipping of the crown rather than bodily movement of the tooth. The virtual plan overestimates the expansion of the teeth; thus, it is reasonable to plan an overcorrection when the arches are highly contracted. These results were in line with the results of Vincent Santucci et al[23] who compared the linear measurements in planning software and cone beam computed tomography (CBCT) to asses buccal tipping and/or bodily translation of the posterior teeth. Results concluded that clear aligner shows dentoalveolar expansion by buccal tipping and bodily translation, ClinCheck® showed a significant overestimation of the amount of expansion capable, with nearly 70% expression in the first premolar area, and the expression decreased as one moved posteriorly with only 35% expressed at the first molar area ($p < 0.0001$).Similarly study by Richard Tien et al[22] concluded that, the predictability of expansion across centroids for the maxillary teeth was: 72.2% canines, 78.9% first premolars, 81.1% second premolars, 63.5% first molars, and 41.5% second molars and the predictability of expansion across centroids for the mandibular teeth was: 82.3% canines, 93.0% first premolars, 87.7% second premolars, 79.8% first molars, and 42.9% second molars. The average expansion was significantly different from that predicted for each type of tooth in both the maxilla and mandible. Both underexpansion and overexpansion were observed hence the authors advised further investigation into factors influencing underexpansion and overexpansion. Jean-Philippe Houle et al[12] investigated the predictability of arch expansion using Invisalign and found the overall accuracy of maxilla to be 72.8% and that of mandible to be 87.7%, similar to studies mentioned above it was found that Clincheck overestimates expansion by body movement; more tipping is observed. Overcorrection of expansion in the posterior region of the maxillary arch seems appropriate. Ning

Zhou et al[14] concluded in his study that aligners could increase the arch width, but expansion was achieved by tipping movement. The evaluation of initial position and preset of sufficient root-buccal torque of posterior teeth were necessary due to the lower efficiency of bodily buccal expansion by the Invisalign system.

5. CONCLUSION

Even though there are insufficient studies in the existing literature regarding the efficacy and predictability of expansion of maxillary arch using clear aligner therapy, after calculation of efficacy and loss in predictability of the final treatment we can conclude from the available data that,
The average efficacy of clear aligner therapy in canine region is 76.51%.
The average efficacy of clear aligner therapy in 1 st premolar region is 82.13%.
The average efficacy of clear aligner therapy in 2 nd premolar region is 79.36%.
The average efficacy of clear aligner therapy in 1 st molar is 66.8%.
The average efficacy of clear aligner therapy in 2 nd molar is 53.3%.
The efficacy of clear aligners to cause maxillary expansion is the highest in the 1st premolar region followed by 2nd premolar region, canine region, 1st molar region and 2 nd molar region.
Based on the results it is recommended to have careful planning with overcorrection and other auxiliary methods of expansion which may help reduce the rate of midcourse corrections and refinements, especially in the posterior region of the maxilla.

6. REFERENCES

1. Castañer-Peiro A. Interceptive orthodontics: the need for early diagnosis and treatment of posterior crossbites. Med Oral Patol Oral Cir Bucal [Internet]. 2006 [cited 2023 May 12];11(2):E210-4. Available from: https://pubmed.ncbi.nlm.nih.gov/16505804/
2. Celikoglu M, Akpinar S, Yavuz I. The pattern of malocclusion in a sample of orthodontic patients from Turkey. Med Oral Patol Oral Cir Bucal [Internet]. 2010;15(5):e791-6. Available from: http://dx.doi.org/10.4317/medoral.15.e791
3. 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. Am J Orthod Dentofacial Orthop [Internet]. 2009;135(1):27–35. Available from: http://dx.doi.org/10.1016/j.ajodo.2007.05.018
4. Fujiyama K, Honjo T, Suzuki M, Matsuoka S, Deguchi T. Analysis of pain level in cases treated with Invisalign aligner: comparison with fixed edgewise appliance therapy. Prog Orthod [Internet]. 2014;15(1):64. Available from: http://dx.doi.org/10.1186/s40510-014-0064-7
5. Miller KB, McGorray SP, Womack R, Quintero JC, Perelmuter M, Gibson J, et al. A comparison of treatment impacts between Invisalign aligner and fixed appliance therapy during the first week of treatment. Am J Orthod Dentofacial Orthop [Internet]. 2007;131(3):302.e1-9. Available from: http://dx.doi.org/10.1016/j.ajodo.2006.05.031
6. Womack WR, Ahn JH, Ammari Z, Castillo A. A new approach to correction of crowding. Am J Orthod Dentofacial Orthop [Internet]. 2002;122(3):310–6. Available from: http://dx.doi.org/10.1067/mod.2002.127477
7. Vlaskalic V, Boyd R. Orthodontic treatment of a mildly crowded malocclusion using the Invisalign System. Aust Orthod J. 2001 Mar;17(1):41-6. PMID: 11506169.
8. Ali SAAH, Miethke HR. Invisalign, an innovative invisible orthodontic appliance to correct malocclusions: advantages and limitations. Dent Update [Internet]. 2012;39(4):254–6, 258–60. Available from: http://dx.doi.org/10.12968/denu.2012.39.4.254
9. Malik OH, McMullin A, Waring DT. Invisible orthodontics part 1: invisalign. Dent Update [Internet]. 2013;40(3):203–4, 207–10, 213–5. Available from: http://dx.doi.org/10.12968/denu.2013.40.3.203
10. 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?: Were the predicted tooth movements achieved? J Orofac Orthop [Internet]. 2012;73(5):365–76. Available from: http://dx.doi.org/10.1007/s00056-012-0097-9
11. 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. Am J Orthod Dentofacial Orthop [Internet]. 2009;135(1):27–35. Available from: http://dx.doi.org/10.1016/j.ajodo.2007.05.018
12. Houle J-P. Arch expansion predictability with Invisalign. 2015.
13. Solano-Mendoza B, Sonnemberg B, Solano-Reina E, Iglesias-Linares A. How effective is the Invisalign® system in expansion movement with Ex30′ aligners? Clin Oral Investig [Internet]. 2017;21(5):1475–84. Available from: http://dx.doi.org/10.1007/s00784-016-1908-y
14. Zhou N, Guo J. Efficiency of upper arch expansion with the Invisalign system. Angle Orthod [Internet]. 2020;90(1):23–30. Available from: http://dx.doi.org/10.2319/022719-151.1
15. 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. Am J Orthod Dentofacial Orthop [Internet]. 2020;158(3):420–5. Available from: http://dx.doi.org/10.1016/j.ajodo.2019.12.015

16. Moher D, Liberati A, Tetzlaff J, Altman DG, Prisma Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS medicine. 2009 Jul 21;6(7):e1000097
17. Kapetanović A, Theodorou CI, Bergé SJ, Schols JG, Xi T. Efficacy of Miniscrew-Assisted Rapid Palatal Expansion (MARPE) in late adolescents and adults: a systematic review and metaanalysis. European journal of orthodontics. 2021 Jun;43(3):313-23
18. Fudalej P, Antoszewska J. Are orthodontic distalizers reinforcedwith the temporary skeletal anchorage devices effective? Am J Orthod Dentofacial Orthop 2011;139:722-9
19. Cozza P, Baccetti T, Franchi L, De Toffol L, McNamara JA Jr. Mandibular changes produced by functional appliances in ClassII malocclusion: a systematic review. Am J Orthod Dentofacial Orthop 2006;129:599.e1-12.
20. Chen Y, Kyung HM, Zhao WT, Yu WJ. Critical factors for the success of orthodontic mini-implants: a systematic review. Am J Orthod Dentofacial Orthop 2009;135:284-91
21. Galluccio G, De Stefano AA, Horodynski M, Impellizzeri A, Guarnieri R, Barbato E, et al. Efficacy and accuracy of maxillary arch expansion with clear aligner treatment. Int J Environ Res Public Health [Internet]. 2023;20(5). Available from: http://dx.doi.org/10.3390/ijerph20054634
22. Tien R, Patel V, Chen T, Lavrin I, Naoum S, Lee RJH, et al. The predictability of expansion with Invisalign: A retrospective cohort study. Am J Orthod Dentofacial Orthop [Internet]. 2023;163(1):47–53. Available from: http://dx.doi.org/10.1016/j.ajodo.2021.07.032
23. Santucci V, Rossouw PE, Michelogiannakis D, El-Baily T, Feng C. Assessment of posterior dentoalveolar expansion with Invisalign in adult patients. Int J Environ Res Public Health [Internet]. 2023;20(5):4318. Available from: http://dx.doi.org/10.3390/ijerph20054318
24. D'Antò V, Valletta R, Di Mauro L, Riccitiello F, Kirlis R, Rongo R. The predictability of transverse changes in patients treated with clear aligners. Materials (Basel) [Internet]. 2023;16(5). Available from: http://dx.doi.org/10.3390/ma16051910
25. Nogal-Coloma A, Yeste-Ojeda F, Rivero-Lesmes JC, Martin C. Predictability of maxillary dentoalveolar expansion using clear aligners in different types of crossbites. Appl Sci (Basel) [Internet]. 2023;13(5):2963. Available from: http://dx.doi.org/10.3390/app13052963
26. Lione R, Paoloni V, Bartolommei L, Gazzani F, Meuli S, Pavoni C, et al. Maxillary arch development with Invisalign system. Angle Orthod [Internet]. 2021;91(4):433–40. Available from: http://dx.doi.org/10.2319/080520-687.1
27. Vidal-Bernárdez M-L, Vilches-Arenas Á, Sonnemberg B, Solano-Reina E, Solano-Mendoza B. Efficacy and predictability of maxillary and mandibular expansion with the Invisalign® system. J Clin Exp Dent [Internet]. 2021;13(7):e669– 77. Available from: http://dx.doi.org/10.4317/jced.58315
28. Morales-Burruezo I, Gandía-Franco J-L, Cobo J, Vela-Hernández A, BellotArcís C. Arch expansion with the Invisalign system: Efficacy and predictability. PLoS One [Internet]. 2020;15(12):e0242979. Available from: http://dx.doi.org/10.1371/journal.pone.0242979
29. Riede U, Wai S, Neururer S, Reistenhofer B, Riede G, Besser K, et al. Maxillary expansion or contraction and occlusal contact adjustment: effectiveness of current aligner treatment. Clin Oral Investig [Internet]. 2021;25(7):4671–9. Available from: http://dx.doi.org/10.1007/s00784-021-03780-4