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Original Research

Accuracy evaluation of orthodontic movements with in- house aligners system: A prospective observational study

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ABSTRACT:

Background: Since the introduction of clear aligner treatment in orthodontics, these aligners have gained popularity among patients, particularly adults, due to their comfort and minimal aesthetic impact. It is a widely used approach in orthodontics for addressing both simple and complex malocclusions. Aim: The aim of this study is to evaluate the accuracy of orthodontic tooth movement with clear aligner treatment. **Method:** The study was conducted on patients undergoing clear aligner treatment with the in-house aligner system in the department. STL files were generated for the planned post-treatment and the actual post-treatment, followed by superimposition in the software to evaluate the actual tooth movement and assess the effectiveness of the in-house clear aligner system. **Results:** Results showed accuracy percentages categorized by movement and tooth. No statistically significant difference was observed between planned and actual movement in most cases. **Conclusion:** This study provided data on the accuracy of tooth movement with the in-house aligner system, along with treatment planning, auxiliary attachments, and corrects diagnosis.

Key words: Orthodontics, Aligners, Accuracy. Auxiliary Attachments, Movement Evaluation, Aesthetic Treatment

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INTRODUCTION

In recent years, an increasing number of adult patients have sought orthodontic treatment and expressed a desire for aesthetic and comfortable alternatives to traditional fixed appliances.[1] The growing popularity of clear aligner therapy is attributed to several advantages, such as aesthetics, enhanced comfort for patients, and improved oral hygiene and periodontal health compared to fixed appliances.[2] The rising awareness of aesthetics has led to advancements in the technique, which is no longer confined to simple crowding cases but has expanded to include complex malocclusions.[3] Kesling was the first to introduce thermoplastic orthodontic devices for minor tooth movements in 1946, a concept later revived by Align Technology (Santa Clara, CA, USA), the first company to produce clear aligners.[4] Over time, aligner technologies have significantly improved; however, challenges remain in cases requiring complex force systems.[5] Issues such as tooth torque, rotation, and bodily movements continue to be difficult with aligner technology.[6] Treatment with aligners follows a stepwise approach: orthodontic tooth movement is virtually planned on a three-dimensional model of the patient's malocclusion, and a sequence of thermoplastic aligners is created to facilitate dental movements.[7] Thus, predicting the accurate tooth movement achieved with aligners in comparison to the planned movement is crucial.[8] Among the earliest studies on Invisalign, the research by Kravitz et al. evaluated the effectiveness of tooth movement using removable polyurethane aligners. This study examined the outcomes of 37 patients treated with clear aligners, comparing actual and predicted tooth movements, and reported an average accuracy of 41%. The least accurate results were observed during extrusion (29.6%), while the most accurate outcomes occurred during lingual

constriction (47.1%), indicating that lingual constriction yielded the highest accuracy for tooth movement using clear aligners.[9] This achievement has motivated manufacturers to enhance the characteristics of clear aligners by adding auxiliary features such as power ridges, bite ramps, precision cuts, and elastics, thus broadening the range of malocclusions that can be effectively addressed with these devices.[10]

Today, a variety of cases are deemed appropriate for orthodontic treatment with aligners, including moderate crowding, distalization, resolution of deep overbites, narrow arch expansion, significant rotation, and space closure or opening.[11] However, there is no established evidence-based consensus in the literature regarding the predictability of different tooth movements with aligners or their impact on root resorption and oral hygiene.[12] Several researchers have indicated that mesio-distal tipping is the most predictable movement, while extrusion and tooth rotations present the greatest challenges.[13] The reported accuracy of movements with clear aligners ranges from 55% to 72%, with canine rotation attaining lower accuracy of less than 36%.[14] The effectiveness of tooth movement is closely linked not only to the virtual setup but also to the mechanical properties of the thermoplastic materials and the designs of attachments utilized.[15] Differences in material properties and thickness of aligners, the production process, model precision, and the positioning of aligner margins all influence the final performance of the appliance, resulting in varying outcomes across different clear aligner systems.[16] Furthermore, the use of aligners in the oral cavity exposes them to factors such as temperature, humidity, salivary enzymes, and elastic deformation that can influence their physical and chemical properties.[17] Aligners experience intraoral aging, which does not alter their chemical composition but does deteriorate their mechanical properties. This degradation can significantly affect the clinical outcomes of clear aligner therapy.[18] It experiences a rapid decline in the force delivered by each aligner due to stress relaxation and intraoral degradation.[19] Given this unpredictability, many clinicians have reported that over half of aligner cases require refinements, corrections, or conversion to fixed appliances.[20] Aligner performance is heavily influenced by the materials used in their construction. In the initial hours of wear, 50% of the initial stress values can dissipate.[21] Among various aligner materials, thicker materials generate greater forces than thinner ones. After 24 hours, orthodontic loads on the aligner and changes in stress influence the intended tooth movement.[22]

Additionally, while studies have focused primarily on the market leader, Invisalign, many alternative systems have emerged since Align Technology's patent expiration.[23] These competing aligner systems differ from Invisalign in construction materials, production processes, margin finishing, and STL model precision; however, the most significant difference may be the professionals involved in treatment planning and setup, whether they are IT specialists, dental technicians, or qualified orthodontists.[24] Alongside Invisalign, the in-house clear aligner system has emerged as a popular alternative for clear aligner therapy.[25] This in-house system encompasses all aspects of setup, from creating a digital model to producing aligners, facilitated by IT specialists, dental technicians, or professional orthodontists. This approach makes it comparatively more affordable and accessible than Invisalign, encouraging a broader population to pursue orthodontic treatment with clear aligners.[26] Therefore, this study aimed to evaluate the actual tooth movement achieved using an in-house clear aligner system. The null hypothesis is that there is no statistically significant difference between the actual tooth movement obtained and the predicted tooth movement.[27]

AIM

This study aimed to evaluate the actual tooth movement obtained by an in-house clear aligner system.

OBJECTIVES

- To evaluate accurate orthodontic tooth movement obtained with clear aligner treatment.
- To assess the difference b/w actual and planned post-treatment tooth movement with clear aligner treatment.

METHODOLOLOGY

Sample size estimation: The study was a prospective investigation conducted in the Department of Orthodontics and Dentofacial Orthopaedics at Shree Bankey Bihari Dental College and Research Centre in Ghaziabad. It involved a sample of 10 patients aged 18 to 45 years who were undergoing clear aligner treatment with the in-house clear aligner system. Tooth movements were evaluated for the maxillary teeth in all participants. Patients were selected based on specific inclusion and exclusion criteria that encompassed a broad range of factors. Analysis was performed after 14 days of aligner wear, with rubber-based putty impressions taken from all patients for actual post-treatment records. The inclusion criteria comprised adult patients with complete permanent dentition, healthy periodontium, and mild crowding and rotations. Conversely, the exclusion criteria included individuals with systemic diseases, periodontal diseases, those requiring extractions, TMJ disorders, and parafunctional habits such as bruxism, dental anomalies including supernumerary teeth and morphological differences, as well as a history of orthodontic treatment.

Armamentarium: Planned stl files of patient, stage models, stl files after archieved tooth movements,

shining 3D extraoral scanner, Meshlab software, Rhino-Rhinoceros 3D software

Procedure: Before the aligner treatment, a thorough case history was recorded for all patients, and all pretreatment records were completed, including intraoral and extraoral photographs, radiographs, and pretreatment study models for treatment planning. All subjects were instructed to wear their aligners for 22 hours per day and to follow the recommended oral hygiene procedures. The aligners were changed every 14 days.

Model Creation and measurements: The patient impression was made using rubber-based putty impression material, and casts were created using type II/III dental plaster. The resulting casts were then scanned with a Shinning 3D model scanner (**Figure 1**), generating STL files (**Figure 2a, 2b**). Arch form software was employed for orthodontic treatment planning, and the STL file was uploaded accordingly. The planned STL file was then transferred to Chitubox software for model printing. Once printed, the models were cleaned, cured, and subsequently thermoformed. The aligner sets were given to the patients for a 14-day wear period. Patients were instructed to return to the clinic after 14 days, at which time post-aligner impressions were taken and converted to STL files using the previously described process. For each treated dental arch, both planned post-treatment (T0) and actual post-treatment (T1) digital casts were available. Subsequently, the actual treatment model (ATM) STL files were overlaid on the planned treatment model (PTM) STL file by a single operator using stable reference points (**Figure 3a, 3b**) in Meshlab software (**Figure 4a, 4b**). The most prominent and stable landmarks were chosen for this process. To enhance the accuracy of the superimposition, the maximum number of points was utilized, focusing on the cusp tips of the canines, premolars, and molars, as well as the incisal edges of the incisors (**Figure 2, 3**). These superimposed files were imported into Rhinoceros software (version 7) for the analysis of linear measurements of each tooth within a 3D Cartesian grid (**Figure 5a, 5b**). The most prominent points on the tooth surface were considered for measuring the changes.

Figure 1: Showing scanning of stone model by shinning 3D scanner to obtain STL files.

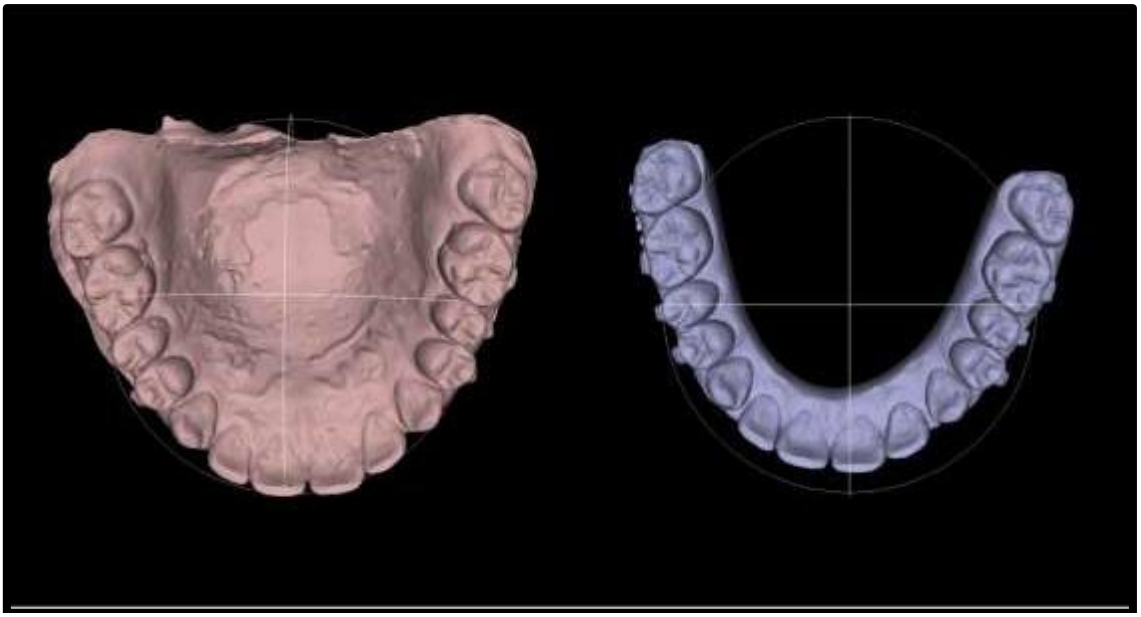


Figure 2a, 2b: Scanned stl files of planned and actual models

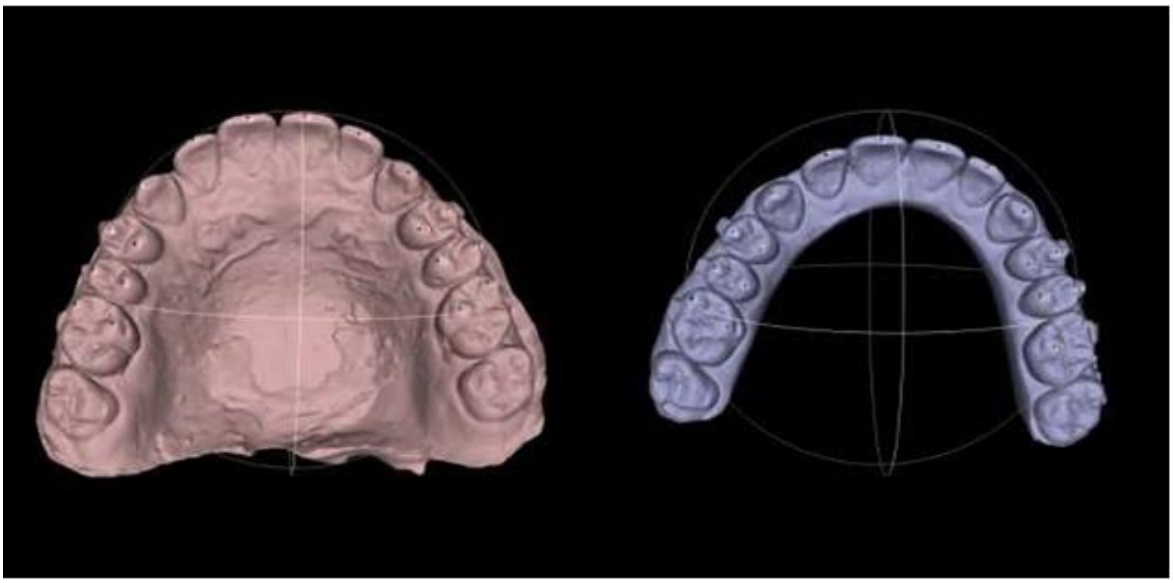


Figure 3a, 3b: Shows the points taken for the super imposition in planned and actual models

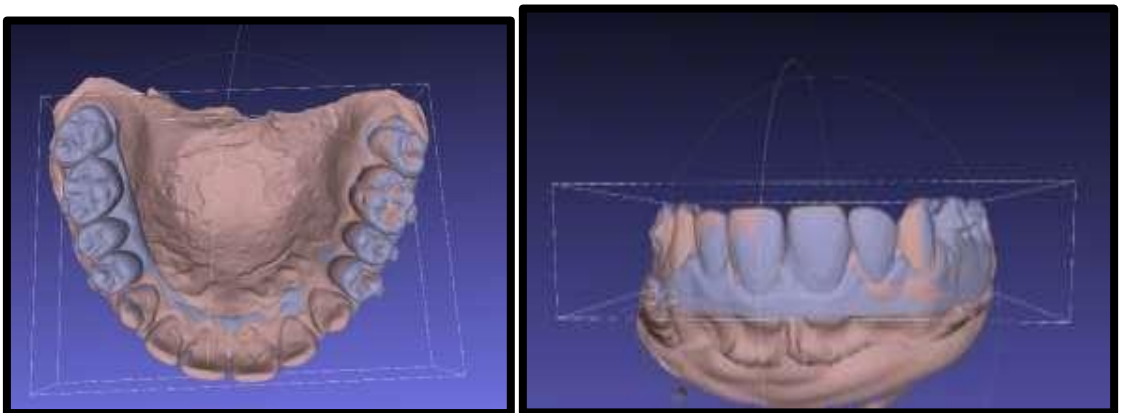


Figure 4a, 4b: Superimposed images of planned model and actual model using meshlab software

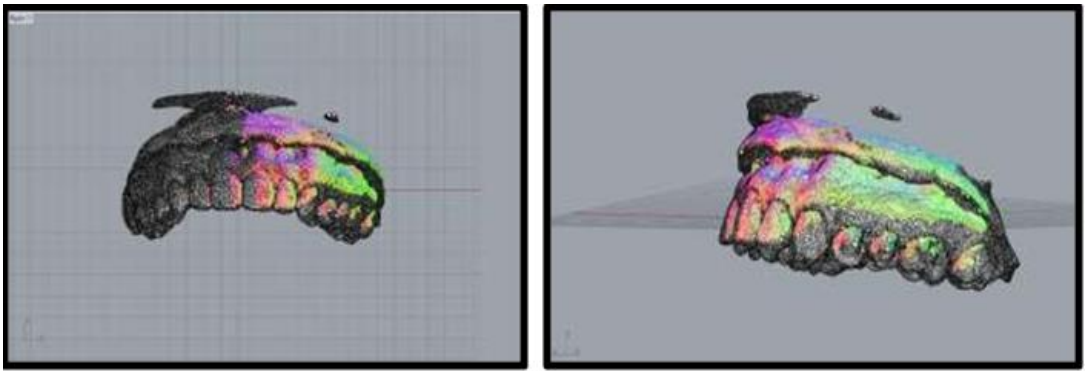


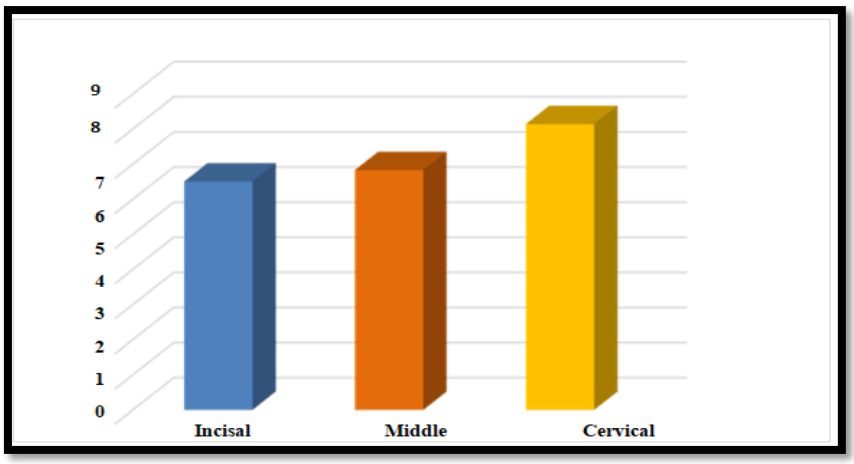
Figure 5a, 5b: Superimposed files for measurement on 3D cartesian grid

RESULTS

Data was carefully entered into a Microsoft Excel spreadsheet and thoroughly checked for inconsistencies. The summarized results were presented through detailed tables and graphs. Analysis was conducted using SPSS (version 21.0), employing the Shapiro-Wilk test to evaluate the normal distribution of variables. Following confirmation of normal distribution, bivariate analyses were performed using One-Way ANOVA, with Tukey's post hoc test for specific comparisons. A statistical significance threshold was set at $p < 0.05$. Measurements of tooth movement were recorded for each aligner after 14 days of intraoral wear, focusing on movement from incisors to molars. Notably, tooth movement was significantly greater in the anterior region compared to the posterior teeth, especially in the incisal region versus the cervical region. As shown in Table 1, a significant overall difference in orthodontic tooth movement was found across the incisal, middle, and cervical regions, with maximum movement at the incisal level and minimum at the cervical level ($p < 0.05$). No significant difference was detected between the incisal and middle regions. Tukey's post hoc comparison revealed the hierarchy of tooth movement as cervical < middle ≤ incisal. **Graph 1 illustrates** that the least tooth movement occurred in the cervical region compared to the middle and incisal areas**. Tables 2, 3, and 4**, along with **graphs 1 and 2**, reinforced these conclusions, indicating substantial movement in anterior teeth. **Graph 2 and table 4** highlights the significant disparity, underscoring minimal movement in the incisors compared to molars and premolars. These findings emphasize the effectiveness of aligners in achieving targeted tooth movements, particularly in the anterior regions, and underscore the importance of precise treatment planning. Overall, significant differences were noted in orthodontic tooth movement across the incisal, middle, and cervical levels using the One-Way ANOVA Test (**Table 1**). Post hoc comparisons indicated maximum movement at the incisal and middle levels compared to the cervical level ($p < 0.05$). A significant difference was also found across molars, premolars, canines, and incisors ($p < 0.05$), confirming that the maximum tooth movement was recorded at the incisal and middle levels (**Table 2**). There is no significant difference in the tooth movement seen among right and left side of the arch, both the side showing significant difference on molars compared to the incisors as depicted in **table 3, graph 3 & graph 4.**

Table 1: Intergroup comparison of orthodontic tooth movements

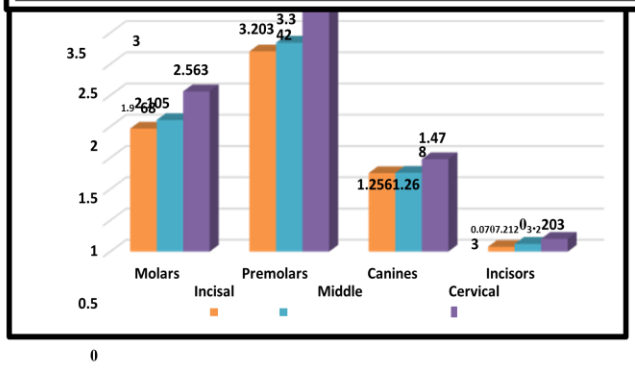
	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Incisal	6.5042	.16704	.05282	6.3847	6.6237	6.27	6.81
Middle	6.8302	.24800	.07842	6.6528	7.0076	6.52	7.20
Cervical	8.1378	.97415	.30805	7.4409	8.8347	6.46	9.62
P value	0.001						
Post hoc	3<2,1						



Graph1: One Way ANOVA Test showing P significance at 0.001; Tukey'stest-Post hoc comparison showing significantly less tooth movement at cervical region compared to incisal and middle third

Table 2: Comparison of orthodontic tooth movement at incisal, middle and cervical level for molars, premolars, canines and incisors

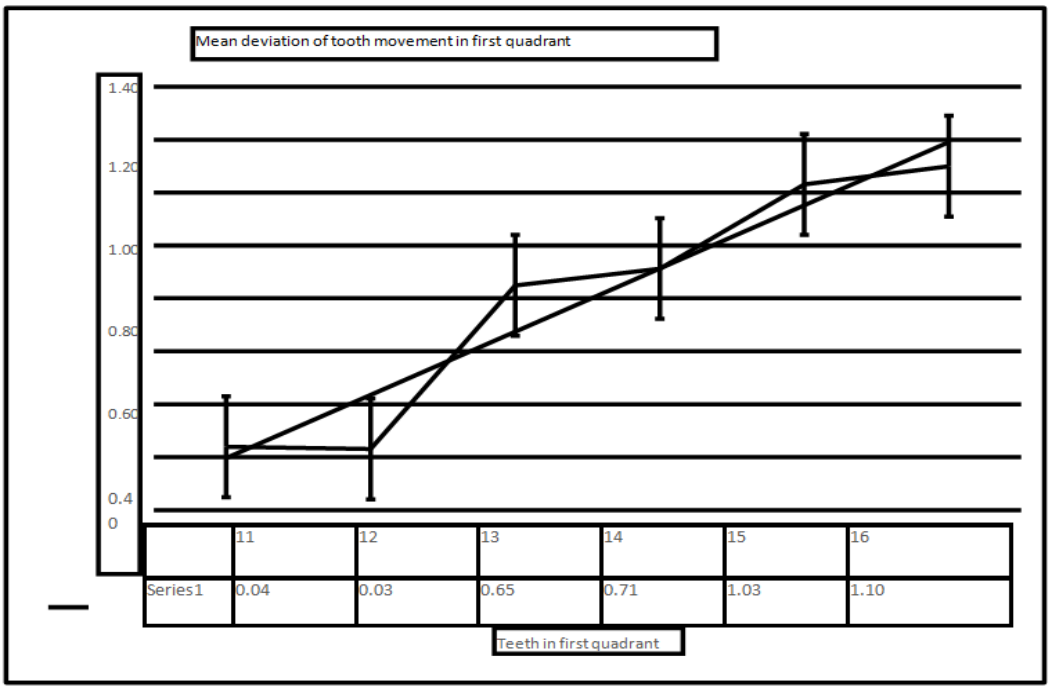
		Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	P value	Post hoc
					Lower Bound	Upper Bound				
Molars	Incisal	1.9680	.01549	.00490	1.9569	1.9791	1.94	1.99	0.001	3<2,1
	Middle	2.1050	.06187	.01956	2.0607	2.1493	2.00	2.18		
	Cervical	2.5630	.42682	.13497	2.2577	2.8683	2.10	3.36		
Premolar	Incisal	3.2030	.15261	.04826	3.0938	3.3122	2.90	3.37	0.001	3<2,1
	Middle	3.3420	.23189	.07333	3.1761	3.5079	2.99	3.80		
	Cervical	3.8935	.62077	.19630	3.4494	4.3376	2.58	4.51		
Canines	Incisal	1.2560	.09095	.02876	1.1909	1.3211	1.11	1.39	0.001	3<2,1
	Middle	1.2600	.09404	.02974	1.1927	1.3273	1.11	1.40		
	Cervical	1.4780	.09953	.03147	1.4068	1.5492	1.36	1.62		
Incisor	Incisal	.0772	.03685	.01165	.0508	.1036	.04	.13	0.001	3<2,1
	Middle	.1232	.05006	.01583	.0874	.1590	.05	.22		
	Cervical	.2033	.06112	.01933	.1596	.2470	.07	.29		



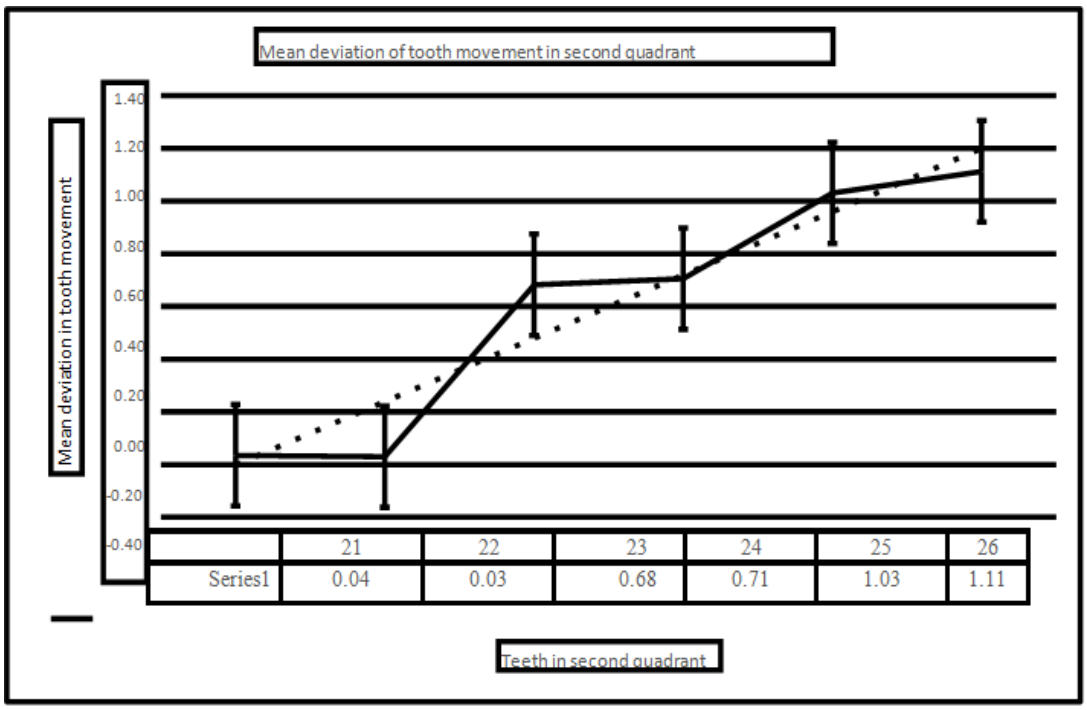
Graph 2: Depicts bar graph diagram showing significant difference of least difference in the incisors compared to molars and premolars

Table 3: Mean standard deviation showing individually for all the teeth of right and left side

Tooth	Mean±SD	Mean±SD	Tooth
11	0.04±0.03	0.04±0.03	21
12	0.03±0.02	0.03±0.02	22
13	0.65±0.09	0.68±0.09	23
14	0.71±0.07	0.71±0.14	24
15	1.03±0.29	1.03±0.24	25
16	1.1±0.17	1.11±0.24	26



Graph 3: Mean deviation of tooth movement in first quadrant



Graph 4: Mean deviation of tooth movement in second quadrant

Table 4: Percentage vestibulo- lingual tipping movement obtained in the orthodontic tooth movement

Tooth	Mean	Mean S.D	%Movement
Central incisor	3.64	0.467	78.3%
Lateral incisor	3.53	0.402	72.01%
Canine	2.53	0.415	63.33%
1st Premolar	2.53	0.391	55.54%
2nd Premolar	2.37	0.387	57.1%

DISCUSSION

In 2005, Djeu et al. highlighted a clear difference between the effectiveness of the Invisalign® system and traditional multi bracket treatment, pointing out that the latter was significantly more effective in achieving favorable occlusal relationships and correcting sagittal discrepancies.[28] A 2019 systematic review by Robertson et al. concluded that clear aligners are comparably effective as fixed orthodontics for correcting mild to moderate malocclusions, although braces may be more suitable for complex cases.[29] The current study aims to evaluate the accuracy of orthodontic tooth movement in the maxillary teeth using custom in-house clear aligners by comparing the intended tooth movements with the actual outcomes.[30] The orthodontic treatment began in adult patients aged 18 years and older, with evaluations conducted after 14 days of aligner wear.[31] Our study revealed that the most significant linear movements occurred in the anterior region compared to the posterior region, with the highest observed value of 1.6 mm in the incisors.[32] Previous research indicated that most intrusions did not exceed 2 mm, likely due to the frequent use of bite ramps and pressure areas.[33] Vestibulo-lingual tipping movements were particularly pronounced in the incisors, comprising approximately 70% of the total movements observed. Additionally, rotational correction was achieved to around 50%.[34] Generally, tipping movements are easier to accomplish than rotational movements in orthodontic treatments. No significant difference in tooth movement was found during the evaluation after 14 days of aligner wear; however, movement was more pronounced in the anterior region compared to the posterior region.[35] In a recent study by Bilello et al. in 2022, the accuracy of tooth movement from pretreatment planning to planned post-treatment and actual post-treatment outcomes was assessed.[36] The study concluded that there was no significant difference between the planned tooth movements and the achieved results. It reported that the overall achieved vestibulo-lingual tipping movement was approximately 90%, with rotational correction achieved to about 80%.[37] Additionally, they noted that overall linear intrusion measurements did not exceed 2 mm.[38] Consistent with prior findings, they observed that movements were more prominent in the anterior region compared to the posterior region.[39]The incorporation of attachments on posterior teeth during orthodontic treatment planning served as a supplementary technique to enhance anchorage and facilitate more intricate tooth movements.[40] Recent systematic reviews evaluating the efficacy of tooth movement with Invisalign®, including the prospective follow-up study by Haouil et al., indicate that vestibulo-lingual (V/L) tipping achieves maximum efficiency, whereas the rotation of canines and premolars shows lower efficiency.[41] A limitation of this study is its smaller sample size and its focus on ongoing clear aligner patients, which resulted in some planned tooth movements not being achieved and therefore not recorded in the study.[42] Numerous studies have been conducted over the years on the accuracy evaluation of orthodontic movements using in-house aligner systems in a prospective observational setting (**Table 5**).[1-20,36]

Table 5: Key findings of various studies done on accuracy evaluation of orthodontic movements with in-house aligners system

Authors	Year	Aim	Sample Size	Methodology	Key Findings	Conclusion
Neal D. Kravitz et al	2008	Evaluate the influence of attachments and inter proximal reduction on canine rotation with Invisalign.	53 canines	Prospective clinical study; measured accuracy using Tooth Measure software.	Mean accuracy of canine rotation was 35.8%. No significant differences between treatment groups (AO, IO, N). Vertical-ellipsoid attachments were most common	Attachments and interproximal reduction do not significantly improve canine rotation accuracy.

					(70.5%).	
Rosvall M. D et al	2009	Quantify laypersons' assessments of orthodontic appliances' attractiveness, acceptability, and value.	50 adults	Computer-based survey with standardized images rated for attractiveness, acceptability, and value.	Attractiveness hierarchy: clear trays > ceramic > self-ligation > metal braces (lowest acceptability 55%). No income effect on ratings.	Patients find common appliances unattractive; willing to pay more for aesthetic options.
Neal D. Kravitz et al	2009	Evaluate the efficacy of tooth movement with Invisalign.	37 patients	Measured predicted vs. achieved tooth movement using Tooth Measure software.	Mean accuracy of tooth movement was 41%; extrusion was least accurate (29.6% for maxillary centrals). Lingual constriction most accurate (47.1%).	Better understanding of tooth movement can guide treatment selection and reduce case refinement.
Melsen B	2011	Discuss changes in orthodontics over recent decades.	N/A	Lecture on orthodontics' evolution concerning appliances, anchorage, and patient demographics	Highlighted shift towards appliance-driven approaches and the rise of adult patients with complex needs.	The field is divided between appliance-driven and orthodontist-driven treatments.
Carl T. Drake et al	2012	Compare orthodontic tooth movement with weekly vs. biweekly aligners.	N/A	Measured tooth movement over 8 weeks with different aligner change intervals.	No significant difference in tooth movement between groups; mean OTM was approximately 1.1 mm.	Material fatigue does not significantly affect the rate of tooth movement.
Xiao-Juan Zhang et al	2015	Assess the accuracy of anterior tooth movement using clear aligners and cone beam computed tomography.	32 patients	Compared predicted and achieved positions using superimposed digital images and models.	Mean discrepancies in crown positions: maxillary 0.376 mm, mandibular 0.398 mm. Root positions differed by 2.062 mm (maxillary) and 1.941 mm (mandibular).	Crowns can be moved accurately, but roots experience less predictable movement with clear aligners.
Rossini G et al	2015	Review the efficacy of clear aligners in controlling orthodontic tooth	11 articles	Systematic review of peer-reviewed articles; assessed methodologic	Maxillary molar distalization showed 88% predictability. Extrusion control was the most challenging	Clear aligners effectively align and level arches but struggle with certain

		movement.		al quality using Cochrane tool.	(30% accuracy).	movements like extrusion.
Lin Feiou et al	2016	Assess the impact of fixed orthodontic appliances vs. clear aligners on daily performance in adults.	152 adults	OIDP index measured at baseline, 6 months, and 12 months post-treatment.	FOA significantly impacted daily performance (eating, cleaning teeth, smiling, social relations), while CA had lesser effects on daily life.	Clear aligners cause fewer impacts on daily life compared to fixed appliances.
Luca Lombardo et al	2016	Investigate stress release properties of thermoplastic materials used for orthodontic aligners.	4 materials	Measured stress release of various aligner materials under load for 24 hours.	All materials exhibited significant stress release, especially within the first 8 hours. Single-layer materials released more stress than double-layer materials.	Material choice significantly affects aligner performance and stress release behavior.
Michele Tepedino et al	2018	Evaluate the movement of anterior teeth using clear aligners.	39 patients	Retrospective analysis of digital models pre- and post-treatment.	No significant differences between predicted and achieved torque movements of anterior teeth.	Clear aligners produce comparable clinical outcomes for anterior torque movements.
Orfeas Charalampakis et al	2018	Assess accuracy of clear aligners in refinement cases.	20 patients	Analyzed predicted vs. achieved movements after initial aligner series.	Horizontal movements were accurate (0.20-0.25 mm differences); maxillary incisor intrusions and rotations showed greater inaccuracies (median difference 1.5 mm for intrusions, 3.05° for rotations).	Intrusions and rotations are less accurate in refinement cases with clear aligners.
Rosaria Bucci et al	2019	Evaluate thickness changes of orthodontic clear aligners after thermoformi	18 patients	Measured thickness of aligners before and after 10 days of use; assessed reproducibility of	Minor but statistically significant thickness changes observed; reproducibility of the thermoforming	Clear aligners show good thickness stability post-thermoforming and after intraoral use.

		ng and intraoral exposure.		thermoforming .	process was high, with maximum Dahlberg's error of 0.13 mm.	
Tamer Ipek, Oztas Evren, Marsan Gulnaz	2019	Review the scientific reality behind marketing clear aligners in orthodontic treatment.	Literature review	Reviewed the demand and characteristics of clear aligners compared to fixed appliances.	Clear aligners are esthetic and comfortable, leading to improved periodontal health and fewer white spot lesions. Suitable for mild to moderate cases; caution is advised for complex cases. Long-term stability studies are needed.	Clear aligners provide a viable alternative to fixed appliances but require careful application in complex cases.
Alessandra Putrino, Ersilia Barbato, Gabriella Galluccio	2021	Scoping review on the evolution and efficiency of clear aligners.	31 studies	Analyzed various characteristics and brands of clear aligners used in Italy through literature review.	Clear aligners have evolved in material and design, but less attention has been given to gingival margin design and auxiliaries. A broader examination beyond Invisalign is needed for comprehensive understanding.	The evolution of aligners enhances efficiency, but further research on diverse systems is essential.
Ho CT et al	2021	Study effects of different aligner materials and attachments on orthodontic behavior.	3D printed typodonts	Utilized different aligner materials and attachment designs to assess canine movement.	BENQ aligners demonstrated less tipping and more bodily movement of canines compared to BIOSTAR and TPU. The type of attachment had minimal effect on movement.	Attachment shape or size has a limited impact on bodily tooth movement; material choice is crucial.
G. Bilello et al	2022	Evaluate the accuracy of orthodontic movements with Invisalign aligners.	Observational study	Analyzed predictability of various tooth movements with the Invisalign system.	Lingual tipping showed high predictability; rotations of canines and premolars were least predictable. Emphasized the	Invisalign demonstrates good accuracy in movements, but larger sample sizes are needed

					need for careful treatment planning and use of auxiliaries for achieving planned outcomes.	for more definitive conclusions.
Vincenzo D'Antò et al	2022	Evaluate predictability of tooth movement with aligners at the end of stage 15.	17 patients	Compared virtually planned and achieved movements at multiple stages using digital models.	Torque corrections were most accurate for second molars, while first molars showed the greatest underperformance. Overall, no significant differences between planned and achieved movements were found.	Accurate evaluation post-aligner treatment is essential for identifying discrepancies in planned movements.

Future Prospects: The advancement of in-house clear aligner systems opens exciting avenues for orthodontic treatment, poised to transform patient care.[37] Future research should prioritize refining digital workflows to enhance the accuracy of tooth movement predictions, utilizing artificial intelligence and machine learning to analyze and optimize treatment outcomes.[38]Additionally, the exploration of innovative materials with superior mechanical properties could improve force delivery and enhance patient comfort.[39]Integrating advanced auxiliary features, such as enhanced attachments and biomechanical aids, may significantly broaden the spectrum of malocclusions that can be effectively addressed.[40] Longitudinal studies will be essential in evaluating the long-term stability of results achieved with in-house aligners. Moreover, incorporating patient-reported outcomes will deepen our understanding of satisfaction and quality of life, fostering a more comprehensive approach to orthodontic care.[41] As technology continues to advance, collaborative efforts among orthodontists, engineers, and data scientists will be crucial in shaping a future that is not only efficient and accessible but also personalized to meet the unique needs of each patient.[42]

CONCLUSION

This study demonstrated notable discrepancies between planned and actual post-treatment tooth movements, highlighting the effectiveness of in-house clear aligner systems in achieving desired orthodontic outcomes. While minimal differences were observed in incisors and the incisal/occlusal region, the molar area showed the greatest variance. The results indicate that anterior tooth movements are more predictable than posterior movements, reinforcing the importance of meticulous case selection and adherence to treatment protocols. As technology evolves, further research is needed to assess long-term stability and explore the integration of advanced materials and digital tools. Ultimately, in-house aligner systems offer a compelling alternative to traditional methods, enhancing patient satisfaction and expanding treatment possibilities for diverse malocclusions.

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Conflicts of interest There are no conflicts of interest

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