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Aligner Rotational “Lag” With In-Office Clear Aligner Therapy

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26 March 2020

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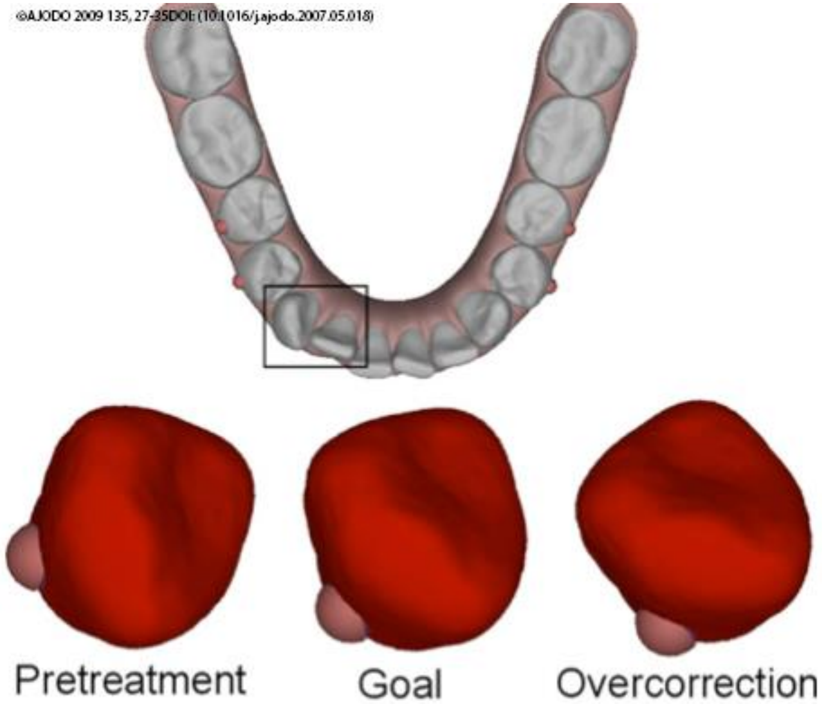
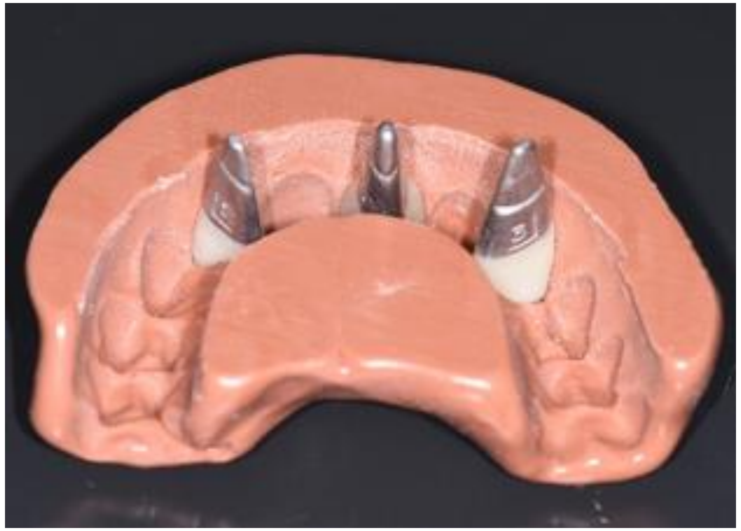
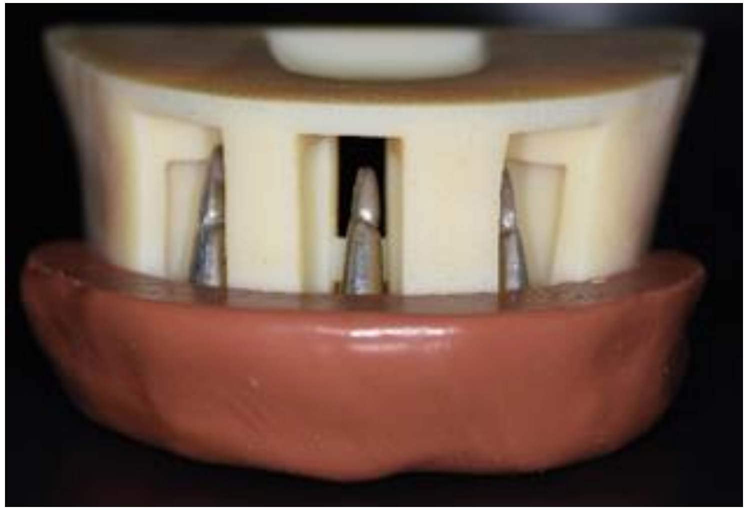
Background and Purpose

- The increase in patient demand for esthetic alternatives and personalized treatment, have given rise to numerous clear aligner systems as alternatives to fixed appliances. However, CAT reportedly does not perform well with incisor extrusion, severe rotations, translation of molars, and closing premolar extraction spaces.
- Oftentimes, once patients complete their aligner sequence, they either require an additional set of aligners or fixed appliance therapy to reach initial treatment objectives. This is what some have termed aligner “lag”. Which can be compared to slot “play” in fixed appliances.
- The purpose of this study was to investigate the amount of rotational “lag” in Clear Aligner Therapy (CAT) in reference to maxillary anterior teeth Null Hypothesis: The null hypothesis was that there would be no differences in “lag” between the groups based on the tooth type.
- In addition, differences of 2° of rotational lag or more were considered clinically relevant



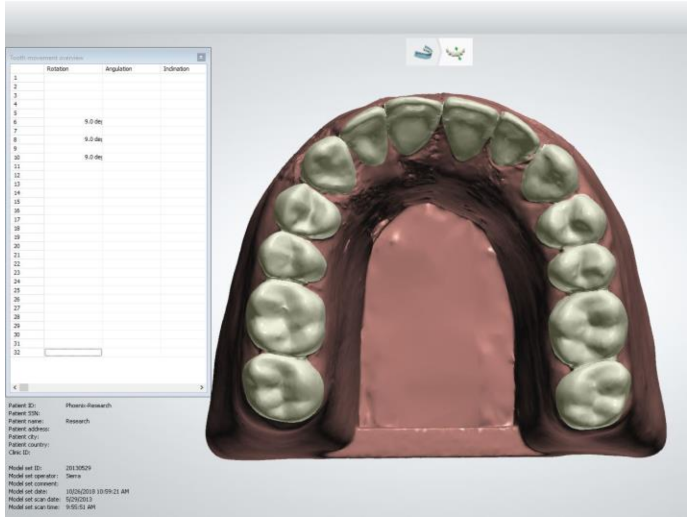
Materials and Methods

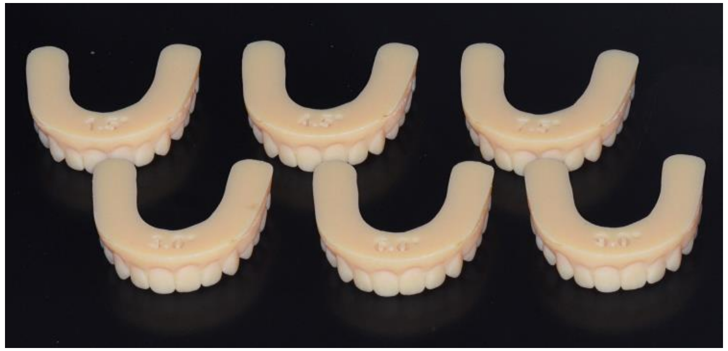
- Step 1: Place metal/plastic teeth in wax dentoform and align in ideal position
- Step 2: Take a digital scan of a wax dentoform (maxilla) with Ideal occlusion (3Shape)
- Step 3: Make a digital model of ideal dentoform using Stratasys Objet Eden260V™ and Polyjet Printer Material (670 Verodent)
- Step 4: On Ideal cast cut out sections with teeth #6, 8 and 10. Replace with wax and corresponding plastic/metal teeth.


Materials and Methods

- Step 5: On 3Shape analyzer, rotate #6, 8 and 10 by 1.5° mesial-lingually to 9° total rotation (6 total .stl files)
- Step 6: .stl files were given to Medical CAD/CAM laboratory and digital models were printed
- Step 7: Made a thermoplastic aligner of digital models (Initial-9°) Essix ACE® Plastic .030 thick (DENTSPLY Raintree Essix Glenroe)
- Step 8: Rotate teeth using sequential aligners in a water bath at 115°F for 5 minutes each with intermittent ice bath (5 minutes) between each aligner
- Step 9: When complete, take 3Shape scan of rotated/final models

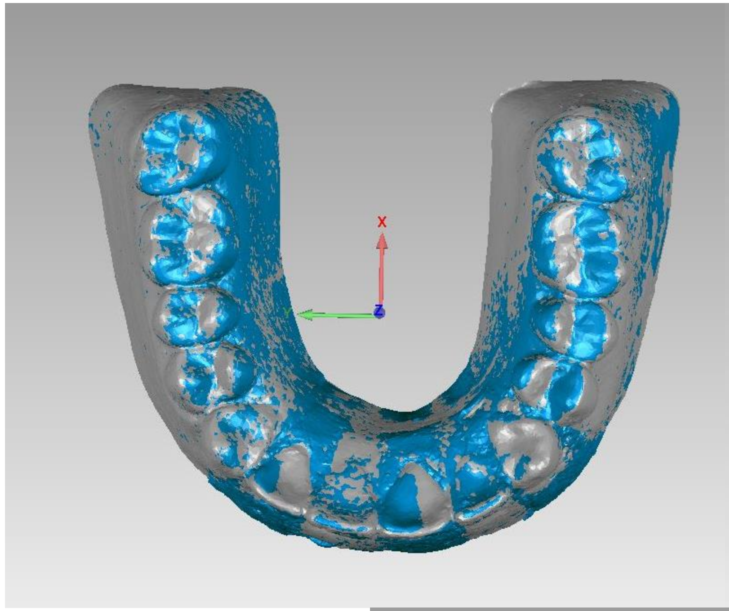


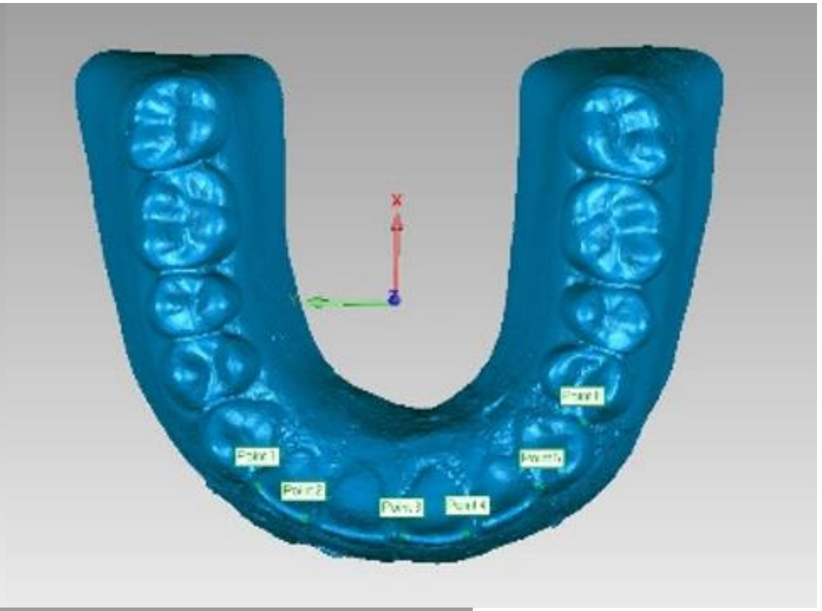


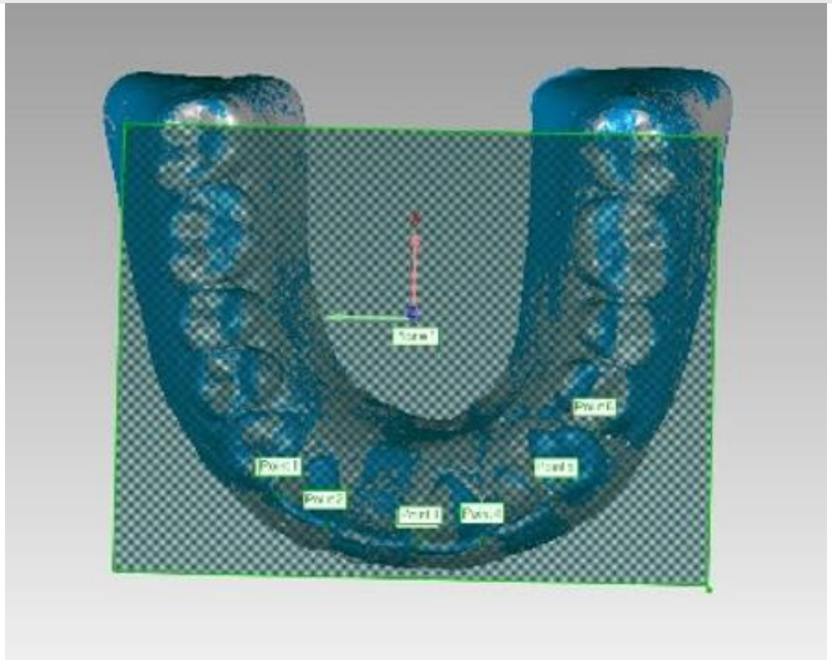
Materials and Methods

Superimposition Workflow

- Step 10: Superimpose initial model scan with final model scan using superimposition software (GeoMagic Studio) (superimpose on non-moving teeth)
- Step 11: Superimposition – Mesiodistal rotations measured by tracing two points on incisal edges of incisors and the most mesial and distal points on canine
- Step 12: Plane created using the mesiolingual cusp tips of the second molars (#2,15) and the middle of the incisal edge of #9.
- Step 13: All points from initial and final scan were then projected to the plane.







#1			#2			#3		
		Angle			Angle			Angle
Tooth 1 cosine	-0.999989711	0.25990507	Tooth 1 cosine	-0.997389882	4.140589821	Tooth 1 cosine	-0.999030911	2.522635906
First Points delta	0.378005924		First Points delta	0.070337615		First Points delta	0.556719268	
Second Points delta	0.047791285		Second Points delta	0.64647131		Second Points delta	0.495306235	
Tooth 2 cosine	-0.992831655	6.864467292	Tooth 2 cosine	-0.99598206	5.137891034	Tooth 2 cosine	-0.994689178	5.907597701
First Points delta	0.517072751		First Points delta	0.610311202		First Points delta	0.564672649	
Second Points delta	0.365788316		Second Points delta	0.265950284		Second Points delta	0.341394928	
Tooth 3 cosine	-0.995415873	5.488226226	Tooth 3 cosine	-0.993514142	6.529145522	Tooth 3 cosine	-0.997965287	3.655635835
First Points delta	0.47172557		First Points delta	0.230643553		First Points delta	0.258082248	
Second Points delta	0.30099184		Second Points delta	0.630998913		Second Points delta	0.522838311	
#5			#6			#7		
		Angle			Angle			Angle
Tooth 1 cosine	-0.998176423	3.460713956	Tooth 1 cosine	-0.999613445	1.593151186	Tooth 1 cosine	-0.999709192	1.381819549
First Points delta	0.276546223		First Points delta	0.429024786		First Points delta	0.37428757	
Second Points delta	0.413076435		Second Points delta	0.402713347		Second Points delta	0.222192567	
Tooth 2 cosine	-0.99481473	5.837288774	Tooth 2 cosine	-0.993066558	6.750925619	Tooth 2 cosine	-0.997205021	4.284775626
First Points delta	0.469278372		First Points delta	0.770593502		First Points delta	0.627919587	
Second Points delta	0.399463847		Second Points delta	0.414074244		Second Points delta	0.246642386	
Tooth 3 cosine	-0.998544363	3.091839029	Tooth 3 cosine	-0.997165877	4.314690006	Tooth 3 cosine	-0.988249424	8.792115607
First Points delta	0.16395849		First Points delta	0.530431711		First Points delta	0.309662635	
Second Points delta	0.361978173		Second Points delta	0.216059995		Second Points delta	0.920777908	
#9			#10			#11		
		Angle			Angle			Angle
Tooth 1 cosine	-0.999431086	1.93277644	Tooth 1 cosine	-0.997528377	4.029194442	Tooth 1 cosine	-0.998722432	2.896516174
First Points delta	0.357850735		First Points delta	0.629643072		First Points delta	0.421926047	

Data

Sample #	Tooth #	Degree	Lag
1	6	5.49	3.51
	8	6.86	2.14
	10	0.26	8.74
2	6	6.53	2.47
	8	5.14	3.86
	10	4.14	4.86
3	6	3.66	5.34
	8	5.91	3.09
	10	2.5	6.5
4	6	0.97	8.03
	8	4.89	4.11
	10	0.63	8.37
5	6	3.09	5.91
	8	5.84	3.16
	10	3.46	5.54
6	6	4.31	4.69
	8	6.75	2.25
	10	1.59	7.41
7	6	8.79	0.21
	8	4.28	4.72
	10	1.38	7.62
8	6	4.9	4.1
	8	4.78	4.22
	10	2.09	6.91
9	6	1.03	7.91
	8	2.66	6.34
	10	1.93	7.07

Method of Analyzing

Superimposition Workflow

- Step 14: Run Script created to compare Initial and Final positions of rotated teeth (#6,8,10)
- Step 15: Compute output data to convert to degrees of rotation (experiment completed 36 times)

Statistical Analysis

Outcome variable will be assessed for normality by the Sapiro-Wilks test

- 3 independent variables (degree rotation of #6,8,10)

Data presented as mean and standard deviation since normally distributed

Statistical Analysis: Repeated Analysis of variance (ANOVA) to determine normality of data to compare 3 different teeth to each other

Significance set to $p<0.05$

N=36 experiments

- based on assumption of standard deviation of 0.15 and to get 95% confidence interval for a true population mean and margin of error of 5%

Results

A repeated-measures ANOVA result indicated that there were significant differences in lag among tooth shapes ($F(2, 105) = 13.14$, $p < .0001$). The Tukey's post hoc test result indicated that the lag with Tooth #8 was significantly smaller than Tooth #6 and Tooth #10. No significant difference in lag was found between Tooth #6 and Tooth #10.

Tooth #	Mean	Std Dev	Min	Max	Lower 95% CL for Mean	Upper 95% CL for Mean
6 (n = 36)	5.46	2.23	0.21	8.80	4.70	6.21
8 (n = 36)	3.12	1.76	0.43	8.49	2.53	3.72
10 (n = 36)	4.95	2.08	1.06	8.74	4.25	5.66

Differences of Least Squares Means									
Effect	Tooth #	Tooth #	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
Tooth #	6	8	2.3350	0.4793	105	4.87	<.0001	Tukey	<.0001
Tooth #	6	10	0.5047	0.4793	105	1.05	0.2947	Tukey	0.5453
Tooth #	8	10	-1.8303	0.4793	105	-3.82	0.0002	Tukey	0.0007

Discussion

Null hypothesis rejected ➡ Significant difference between groups

Statistically significant difference between central and lateral incisor

Statistically significant difference between central incisor and canine

No statistically significant difference between the lateral incisor and canine

Discussion

- The results of the current study resemble those of others that found derotations of canines to have relatively poor accuracy. Derotations of cylindrical teeth (canines and premolars) most difficult.
  - Clear aligner loses anchorage and slips off due to absence of undercuts and round tooth shape
- Need attachments for counter-moments to occur
- Use of interproximal reduction (IPR) can also positively influence the correction of derotations.

ORIGINAL ARTICLE

How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign

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Introduction: The purpose of this prospective clinical study was to evaluate the efficacy of tooth movement with removable polyurethane aligners (Invisalign, Align Technology, Santa Clara, Calif). **Methods:** The study sample included 37 patients treated with Anterior Invisalign. Four hundred one anterior teeth (198 maxillary and 203 mandibular) were measured on the virtual Treat models. The virtual model of the predicted tooth position was superimposed over the virtual model of the achieved tooth position, created from the posttreatment impression, and the 2 models were superimposed over their stationary posterior teeth by using ToothMeasure, Invisalign's proprietary superimposition software. The amount of tooth movement predicted was compared with the amount achieved after treatment. The types of movements studied were expansion, constriction, intrusion, extrusion, mesiodistal tip, labiolingual tip, and rotation. **Results:** The mean accuracy of tooth movement with Invisalign was 41%. The most accurate movement was lingual constriction (47.1%), and the least accurate movement was extrusion (29.6%)— specifically, extrusion of the maxillary (18.3%) and mandibular (24.5%) central incisors, followed by mesiodistal tipping of the mandibular canines (26.9%). The accuracy of canine rotation was significantly lower than that of all other teeth, with the exception of the maxillary lateral incisors. At rotational movements greater than 15°, the accuracy of rotation for the maxillary canines fell significantly. Lingual crown tip was significantly more accurate than labial crown tip, particularly for the maxillary incisors. There was no statistical difference in accuracy between maxillary and mandibular teeth of the same tooth type for any movements studied. **Conclusions:** We still have much to learn regarding the biomechanics and efficacy of the Invisalign system. A better understanding of Invisalign's ability to move teeth might help the clinician select suitable patients for treatment, guide the proper sequencing of movement, and reduce the need for case refinement. (Am J Orthod Dentofacial Orthop 2009; 135:27-35)

In 1998, Align Technology (Santa Clara, Calif) introduced Invisalign, a series of removable polyurethane aligners, as an esthetic alternative to fixed labial braces. The Invisalign system uses CAD/CAM stereolithographic technology to forecast treatment and fabricate many custom-made aligners from a single impression.[1] Each aligner is programmed to move a tooth or a small group of teeth 0.25 to 0.33 mm every 14 days.[2] This unique method of tooth movement has involved more adults with orthodontic therapy. In the past decade, Invisalign has been used to treat over 300,000 people worldwide,[3,4] most of them above 19 years of age.[5]

As Invisalign continues to grow in consumer demand and professional use, questions regarding the efficacy of this system remain. How well do removable aligners move teeth? Align Technology reports that 20% to 30% of patients treated with Invisalign might require either mid-course correction or refinement impressions to help achieve the pretreatment goals.[2] However, many orthodontists report that 70% to 80% of their patients require midcourse correction, case refinement, or conversion to fixed appliances before the end of treatment.[6,7]

There are few substantive controlled clinical trials pertaining to Invisalign. Lagravère and Flores-Mir[8] conducted a systematic review of the literature about the Invisalign system and found that it did not offer scientific evidence regarding the indication, efficacy, limitations, or treatment effects of Invisalign. To date, published data have primarily included case reports, commentaries, material studies, surveys, descriptive

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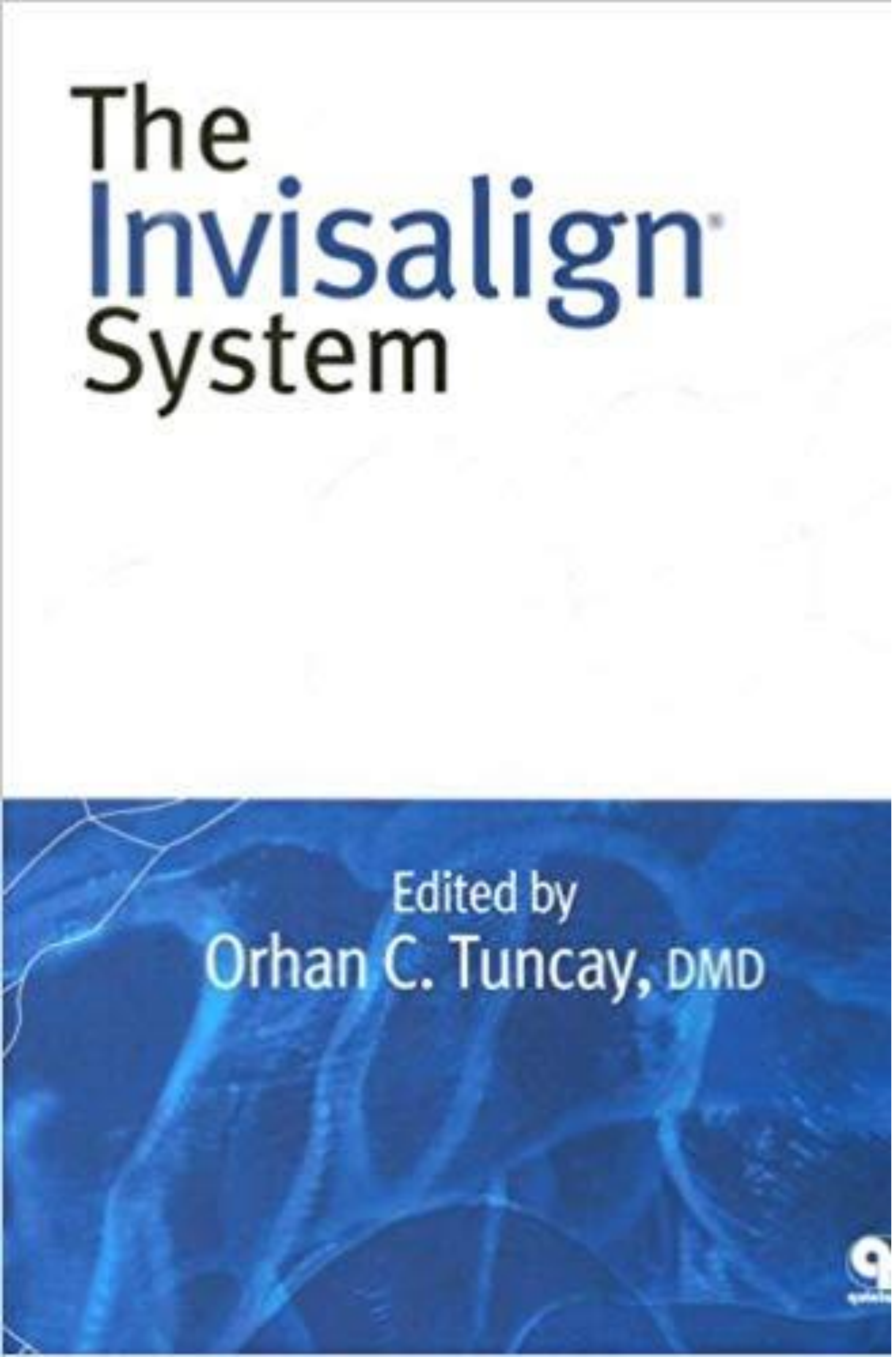
Submitted, March 2007; revised and accepted, May 2007.
0889-5406/$36.00

doi:10.1016/j.ajodo.2007.05.018

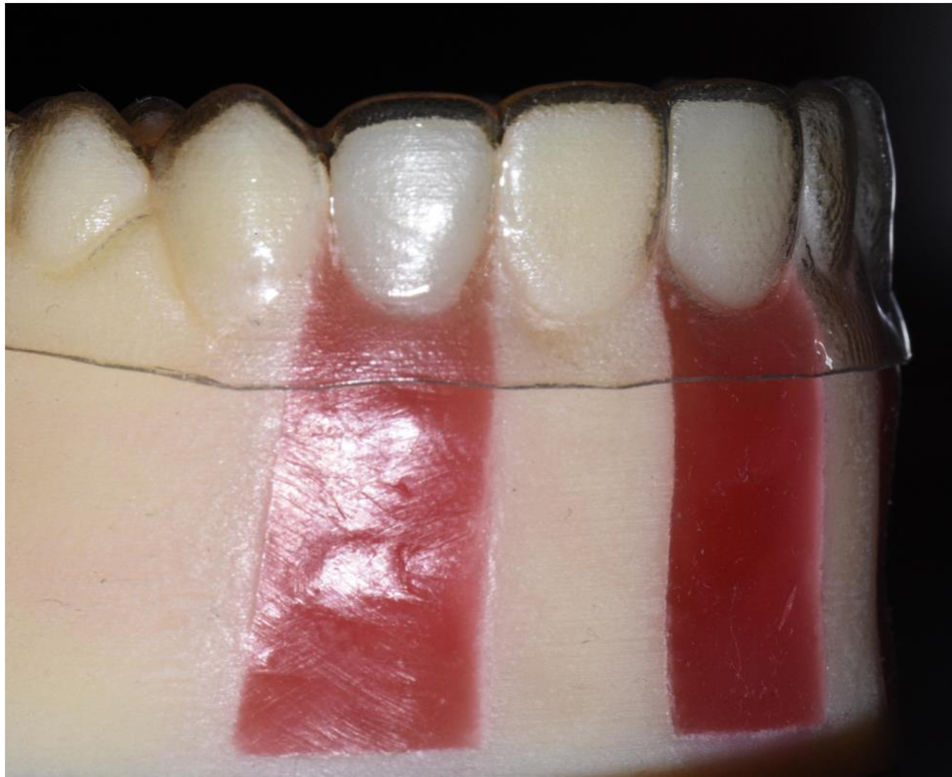


Discussion

- The highest accuracy of rotation, or least amount of lag, was achieved by the maxillary central incisor. These results are similar to those of Kravitz et al. and Nguyen and Cheng who reported that incisors achieved the highest accuracy of rotation and canines and premolars the lowest accuracy of rotation.
- The lateral incisor on the other hand, in this in vitro study, did not respond as per previous studies. In Kravitz et al.'s study, there were no statistically significant differences in rotations among incisors (max or man). Leading Kravitz to believe that shape may have a greater influence than size in reference to derotations with Invisalign.
- In this study, the inability of the clear aligner to derotate the lateral incisor may have been more an aspect of the study limitations.

Study Limitations

- Using 0.30mm Essix material without auxiliaries in an in vitro setting
- Lateral incisor tended to intrude into the wax and out of tray more often than the canine and the central incisor. Hence, incomplete seating of lateral incisor possibly affecting amount of rotation.
- Water temperature was difficult to maintain at 115°F. More of a range (112°F –119°F).
- Initial position of the plastic teeth may have been affected when placing the melted wax into the stent. A more rigid stent that held the crowns of the plastic teeth more securely while melted wax was poured to hold them in place, would have helped with this aspect of the study.
- The occlusal force that is provided by tray seaters (chewies) or opposing dentition/aligner to continuously seat the aligner was also absent from this study since there were no forces on the aligners while they were in the water bath.



This study vs. Others

In vitro

Isolated movement of specific teeth to assess aligner rotational lag

Improved Superimpositions due to non-moving teeth

Specified new method of analyzing degrees of rotation

Conclusions

1

Clear aligner therapy, without attachments, was more effective in rotating central incisors than lateral incisors and canines.

2

Clear aligner therapy, without attachments, did not achieve the complete rotation of either the central incisor, the lateral incisor, or the canine.

3

An in-vitro way of manipulating and observing specific tooth movements using digital scanning and digital models.