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Perceived efficacy of extrusion of maxillary lateral incisors with aligners

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Perceived efficacy of extrusion of maxillary lateral incisors with aligners

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

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Abstract

PERCEIVED EFFICACY OF EXTRUSION OF MAXILLARY LATERAL INCISORS WITH
ALIGNERS

By: Mason T. Bates, D.D.S.

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
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Thesis Advisor: Bhavna Shroff, D.D.S., M.Dent.Sc., M.P.A.

Virginia Commonwealth University Department of Orthodontics Program Director

Purpose: To assess the perceived efficacy of aligners (Invisalign, Align Technology Inc) at

performing extrusive movements of maxillary lateral incisors, determine a general threshold of

when a maxillary lateral incisor is not extruding as predicted and requiring intervention, evaluate

the frequency and methods of intervention to achieve the predicted extrusion, and to evaluate any

related differences between orthodontists and general dentists, and between clinicians having

treated various numbers of patients with Invisalign in the past 12 months.

Methods: An original 18-question survey was sent by mail to a randomized and geographically

proportionate selection of orthodontic specialists (N = 400) and general dentists (N = 400) who

were listed as providers on the Invisalign website. The data were analyzed using ANOVA and chi-

square tests.

Results: 126 providers responded to the survey (15.8% response rate), including 36 general

dentists and 90 orthodontists. Overall, the average perceived efficacy was 4.71 out of 10 (95%

CI: 4.28-5.14). The threshold for determination of tracking issues was significantly associated

with provider type, with orthodontists more often using 0.5mm as their threshold compared to

general dentists (p=0.0305). General dentists were significantly more likely to prefer an optimized attachment (p=0.0001), whereas orthodontists were significantly more likely to prefer a gingivally beveled horizontal rectangular attachment (p<0.0001). No clear agreement existed among clinicians on percent of cases in which they experience tracking issues when extruding maxillary lateral incisors. Refinement scan was the most common method of intervention, followed by the bootstrap technique.

Conclusions: Average perceived efficacy for extruding maxillary lateral incisors with aligners was 4.71 out of 10. Orthodontists had a lower tolerance than general dentists for tracking issues (0.5 mm vs 1.0 mm, respectively). Refinement scan was the most common method of intervention. General dentists and orthodontists differed in their treatment planning preferences and timing of intervention.

Introduction

Technological advancements, such as intraoral scanning, three-dimensional imaging, digital treatment planning, three-dimensional printing, and clear aligners, have transformed the specialty of orthodontics. In 1998, after receiving clearance from the U.S. Food and Drug Administration (FDA), Align Technology (Santa Clara, CA) introduced their system to the market with direct advertising to the public.[1] Since then, clear aligners have quickly grown in popularity as an esthetic, comfortable, and personalized treatment option. Aligners, among other more esthetic treatment options, has dramatically increased the number of adults seeking orthodontic treatment.

Despite their popularity, there have been limited studies quantifying the effectiveness of aligners.[2–5] Early studies revealed significant limitations.[6–8] Clear aligner treatment has substantially improved over the years through the incorporation of attachments, interarch elastics, bite ramps, and new aligner materials. For Invisalign specifically, the G4 (released on Nov 14, 2011) and G7 (released on Oct 17, 2016) product innovations indicated that they could deliver improved control of maxillary lateral incisors, teeth that commonly do not move as predicted.[1,9] However, despite these improvements, extrusion of maxillary lateral incisors remains a difficult movement to achieve with aligners.

Few studies specifically measured the efficacy of extruding maxillary lateral incisors with aligners. Kravitz et al[8] evaluated the efficacy of expansion, constriction, intrusion, extrusion,

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mesiodistal tip, labiolingual tip, and rotation in anterior teeth with Invisalign and determined the mean accuracy of tooth movement to be 41%, with extrusion being the most difficult movement. In their study, the extrusion of maxillary lateral incisors had a mean accuracy of 28.4%. Krieger et al[10] evaluated how closely the ClinCheck prediction corresponded to actual treatment results and determined that the concordance regarding overbite correction was 14.3%, affirming that, at least at that time, Invisalign had difficulty achieving planned vertical tooth movements in the anterior region. These authors advised that vertical overcorrection, case refinement, or supportive measures, such as horizontally beveled attachments or elastics, be considered in order to achieve treatment goals. In a follow-up study by Krieger et al[11] that assessed Invisalign treatment in the anterior region, it was affirmed that movements in the vertical plane were more difficult to achieve, with an average deviation of -0.71 mm from predicted. In contrast, Grunheid et al[12] found no significant differences in the predicted and achieved occlusal-gingival position of the maxillary lateral incisors, and Charalampakis et al[13] found that extrusion of maxillary lateral incisors was accurate. In a recent follow-up to the 2009 study by Kravitz et al[8], Haouili et al[14] sought to provide an updated evaluation of the accuracy of tooth movement with Invisalign. Their study found an overall accuracy of 50%, and an accuracy of 53.7% for maxillary lateral incisor extrusion. Both of those values reflected an improvement from the original study and were likely an underestimate of clinical efficacy due to over-correction incorporated in the ClinChecks in their study. Nonetheless, the authors found that the strengths and weaknesses of tooth movement with Invisalign remained consistent with previous findings. Despite the conflicting evidence, clinicians agree that extrusion of maxillary incisors, as well be bodily expansion of maxillary posterior teeth, canine and premolar rotation, and deep bite correction, are challenging movements to accomplish with aligners alone.[4,5]

Though it is known that extruding maxillary lateral incisors with aligners is challenging and issues with tracking (teeth not following the planned movements and therefore not appearing to fit properly in the aligner) are not uncommon, few specific recommendations have been proposed. In 2007, prior to many product improvements, Boyd[15] recommended slowing down difficult tooth movements to less than the standard velocity per stage. Nicozisis[16,17] recommended using an optimized extrusion attachment, but also to procline the tooth first to create interproximal space, and then simultaneously extrude and retract the tooth (1:1 ratio), prior to closing the interproximal space. Glaser[18] recommended placing a 4 mm wide gingivally-beveled horizontal attachment on the facial surface of maxillary lateral incisors when absolute extrusion is desired.

Additionally, the literature reports that a considerable number of general dentists offer orthodontic treatment to their patients, many of which are using Invisalign as their treatment modality.[19–28] Though it is relatively simple to become certified as a provider, Vicéns and Russo[24] found that most general dentists and orthodontists were not comfortable with treating patients with Invisalign, or understanding how it works, after initial certification alone. Patients may not always be able to discern the difference, but studies show that they are more likely to receive better treatment results and spend less time in treatment when they are treated by an orthodontist as opposed to a general practitioner.[22,25] It has also been reported that orthodontists spend more time reviewing a ClinCheck, are more likely to do refinements, and use a wider variety of appliances, auxiliaries, and techniques.[26,27]

The purpose of this cross-sectional study was to evaluate the perceived efficacy of aligners at performing extrusive movements of maxillary lateral incisors, to establish a general threshold for considering a maxillary lateral incisor to not be extruding as predicted and requiring intervention, to evaluate the frequency and methods of intervention, and to evaluate any related

differences between orthodontists and general dentists and between clinicians having treated various numbers of patients with aligners in the past 12 months. This knowledge will help clinicians determine how to better achieve this challenging tooth movement, and when and how to intervene when tooth movement is not happening as predicted. The null hypothesis was that there would be no differences in the treatment planning preferences of orthodontists and general dentists for the extrusion of maxillary lateral incisors with aligners, nor when and how to intervene if a maxillary lateral incisor is determined to not be extruding as predicted.

Methods

Approval for this cross-sectional study was obtained from the institutional review board at Virginia Commonwealth University (HM20018487). An original 18-question survey was sent by mail to a randomized and geographically proportionate selection of orthodontic specialists (N = 400) and general dentists (N = 400) who were listed as providers on the Invisalign website. After six weeks, a second mailing was sent out to providers who did not respond to the first mailing. The survey questions were designed to collect information on the providers' practice characteristics, perception of the efficacy of aligners at extruding maxillary lateral incisors, and treatment planning and intervention preferences when extruding maxillary lateral incisors with aligners.

First, clinicians were asked to provide information related to their practice such as how long they had been in practice, how long they had been an Invisalign provider, how many patients they had treated with Invisalign in the past 12 months, what percentage of their orthodontic patients were treated with Invisalign, and their recall preferences. Providers were then asked to report their perception of how effective aligners are at extruding maxillary lateral incisors (Visual Analog Scale from 1 to 10, with 1 being "ineffective" and 10 being "very effective"), the frequency of tracking issues with maxillary lateral incisors in their practice, what type of case presents the greatest likelihood of encountering a tracking issue, and how they measure if a tooth is tracking or not.

In order to determine a general threshold for providers to use when considering if a maxillary lateral incisor is tracking, a digital impression was taken of a maxillary typodont *(Align Technology Inc, San Jose, CA)* with an iTero Element 2 intraoral scanner *(Align Technology Inc, San Jose, CA)*. The digital model was uploaded into Meshmixer *(Autodesk, San Rafael, CA),* where the upper left maxillary lateral incisor was altered to appear as if it was intruded at various intervals (0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm) relative to the adjacent teeth, as shown in Figure 1. The digitally altered models, as well as the original model, were 3D printed in SprintRay Model White resin *(SprintRay, Los Angeles, CA)* using a MoonRay 3D Printer *(SprintRay, Los Angeles, CA)*. Following printing, each of the models were post-processed by using a Form Wash *(Formlabs Inc, Somerville, MA)* automated washing machine for 45 minutes and curing in UV light for 60 minutes. A clear thermoplastic material, Duran Material Clear 0.625 mm *(Scheu Dental Technology, Iserlohn, Germany),* was used to create a clear aligner based on the original unaltered model. The aligner was seated on each of the altered models so that it would appear that the maxillary lateral incisor was not tracking at various levels of discrepancy (0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm). Standardized photographs were taken of each of the models so that the discrepancies between the aligner and the maxillary left lateral incisor were clearly visible, as shown in **Figure 2**. Study participants were given the aligner thickness and a picture of each model and then were asked to specify at which discrepancy they would first begin to determine that the maxillary lateral incisor is not tracking with the aligners.

1.5 mm intrusion
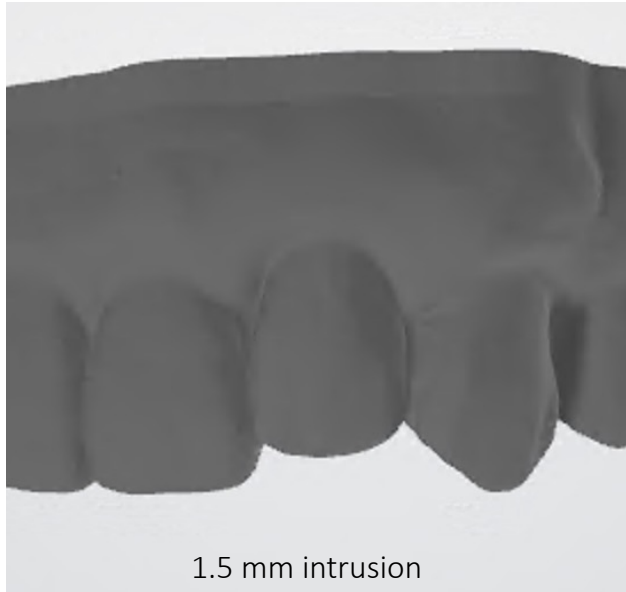
Figure 1: Digitally altered model in Meshmixer
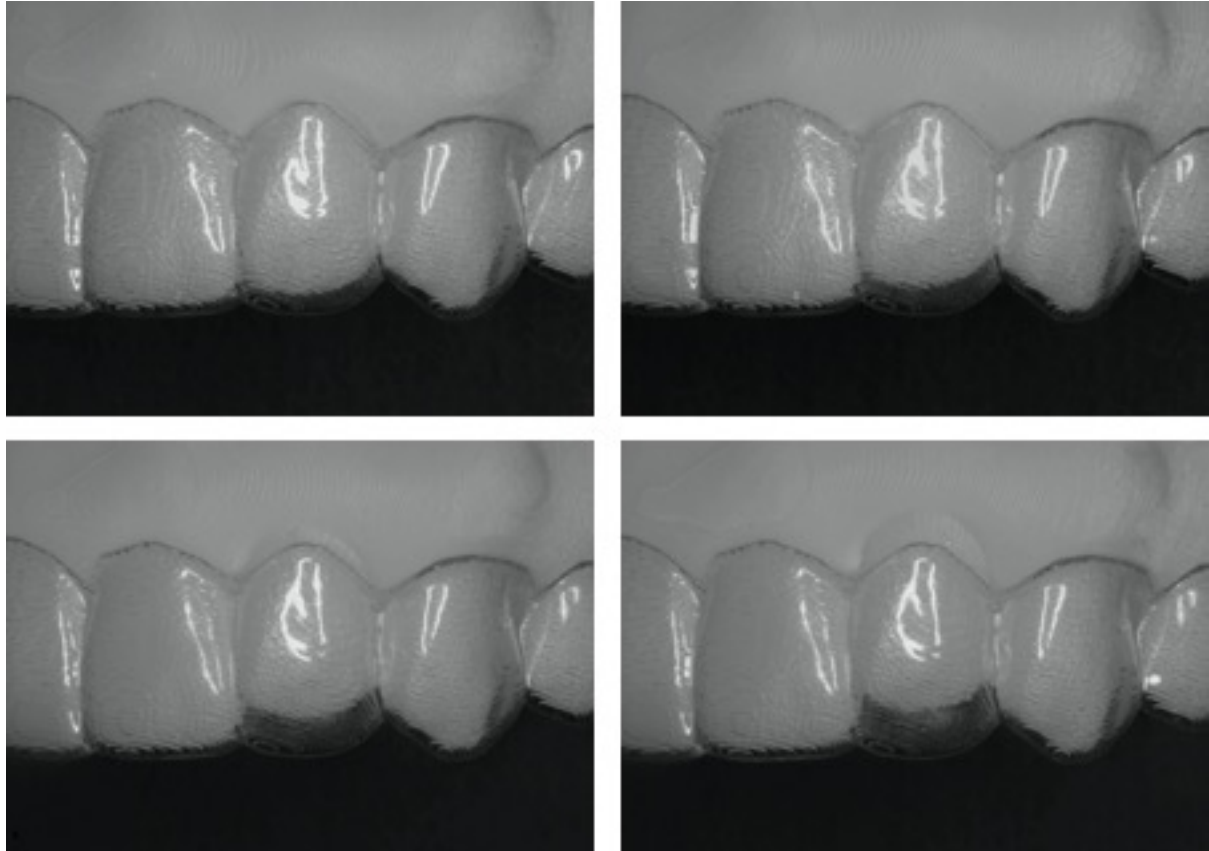
Figure 2: Standardized photographs displaying tracking discrepancies of 0.5 mm (top left), 1.0 mm (top right), 1.5 mm (bottom left), and 2.0 mm (bottom right)

Regarding treatment management, providers were asked to report on what types of attachments or modifications they request in their ClinChecks, as well as which single option they prefer, when planning to extrude a maxillary lateral incisor with aligners. This question was asked for both the facial and palatal tooth surfaces. Lastly, providers were asked to report their preference for intervention, if any, when they determine that a maxillary lateral incisor is not extruding as predicted.

All data collected were deidentified prior to analysis. Responses were summarized using counts and percentages for categorical variables and means and standard errors for continuous measures. Differences in the perceived efficacy were compared using ANOVA with Tukey's adjusted post hoc pairwise comparisons. Associations between respondent demographics and selections for treatment methods and perceptions were compared using chi-square tests. Significance level was set at 0.05. SAS EG v.8.2 (SAS Institute, Cary, NC) was used for all analyses.

Results

A total of 800 surveys were sent, of which 2 were returned as non-deliverable. 126 providers responded to the survey (15.8% response rate), including 36 general dentists (28.6% of respondents) and 90 orthodontists (71.4% of respondents). Most respondents had more than 10 years in practice (81% for general dentists and 79% for orthodontists, p=0.8346). Orthodontists reported treating a higher number of Invisalign cases in the past 12 months, with 60% of orthodontists compared to 12% of general dentists having treated more than 50 cases (p<0.0001). Although responding orthodontists treated a greater total quantity of cases with Invisalign in the past 12 months, general dentists reported treating a greater percentage of their total orthodontic cases with Invisalign. For general dentists, 61% reported treating 75-100% of their cases with Invisalign, compared to only 6% of orthodontists who reported treating that percentage of their cases with Invisalign (p<0.0001). For both groups, about 15% reported using virtual monitoring (14% vs 17%, p=0.7916). Demographics are summarized in **Table 1**.

Table 1: Summary of Respondents. Format of cell values is "n (%)".

	General Dentist	**Orthodontist**	**P-value**
Years in Practice			
Less than 10 Years	7 (19%)	19 (21%)	0.8346
10 or More	29 (81%)	71 (79%)	
Virtual Monitoring			
Yes	5 (14%)	15 (17%)	0.7916
No	31 (86%)	73 (83%)	
Invisalign Cases in Past 12 Months			
0-50	31 (89%)	36 (41%)	<0.0001

51-100	3 (9%)	19 (22%)	
101+	1 (3%)	33 (38%)	
Percent Invisalign			
0-10%	6 (17%)	27 (31%)	<0.0001
11-25%	1 (3%)	31 (35%)	
26-50%	5 (14%)	18 (20%)	
51-74%	2 (6%)	7 (8%)	
75-100%	22 (61%)	5 (6%)	

Respondents indicated on a 10-point scale how effective they perceived Invisalign to be at performing extrusive movements of maxillary lateral incisors. Overall, the average perceived efficacy was 4.71 out of 10 (95% CI: 4.28-5.14). The average perceived efficacy ratings were significantly associated with number of Invisalign cases in the past 12 months (p=0.0195) and percent of orthodontic cases treated with Invisalign (p=0.0380). Ratings were not significantly associated with provider type (p=0.9051) or years in practice (p=0.2494). Clinicians who treated over 100 cases in the past 12 months reported an average effectiveness of 5.65, which was significantly higher than the average rating of 4.28 for those who treated 0-50 (adjusted p=0.0141) and not significantly higher than those who treated 51-100 cases who reported an average of 4.45 (adjusted p=0.1427). Those who treated 26-50% of their orthodontic cases with Invisalign rated the effectiveness the highest on average at 5.7, which was significantly higher than those who treated 0-10% of their orthodontic cases with Invisalign who rated the effectiveness 3.94 on average (95% CI on difference: 0.06-3.45; adjusted p=0.0382). This was the only significant difference based on percent of orthodontic cases treated with Invisalign. A summary of the average perceived effectiveness scores is given in **Table 2**

Table 2: Average (SE) Perceived Effectiveness for Extruding Maxillary Lateral Incisors. P-value from ANOVA, levels not connected by the same level are significantly different from Tukey's post hoc comparisons.

	Mean	**SE**	**P-value**

Overall	4.71	0.22	
Provider Type			0.9051
General Dentist	4.75	0.41	
Orthodontist	4.69	0.25	
Invisalign Cases in Past 12 Months			0.0195
0-50	4.28	0.28	a
51-100	4.45	0.49	a,b
101+	5.65	0.4	b
Years in Practice			0.2494
Less than 10 Years	5.19	0.47	
10 or More	4.58	0.24	
Percent Invisalign Cases			0.038
0-10%	3.94	0.4	a
11-25%	4.38	0.4	a,b
26-50%	5.7	0.48	b
51-74%	4.44	0.76	a,b
75-100%	5.3	0.44	a,b

Overall, 54% of respondents reported 0.5mm as the general threshold for considering a maxillary lateral incisor to not be extruding as predicted and requiring intervention. The remaining 46% indicated 1mm. This selection was significantly associated with provider type, with orthodontists using 0.5mm as their threshold more so than general dentists (67% vs 39%, p=0.0305). The threshold was also significantly associated with the number of Invisalign cases treated in the past 12 months (p=0.0316), with 74% of those treating greater than 100 cases reporting 0.5mm compared to 45% for those treating 51-100 and 48% for 0-50. The threshold was not significantly associated with years in practice (p=0.1914) or the percent of orthodontic cases treated with Invisalign (p=0.3669). Nearly all respondents (n=119, 97%) reported visually confirming tracking issues rather than measuring with a probe (n=4, 3%). Summary of selections are given in **Table 3**.

Table 3: Threshold for Intervention of Tracking Issues. Format of cell values is "n (%)".

	0.5mm	1.0mm	P-value

Overall	67 (54%)	57 (46%)	
Provider Type			0.0305
General Dentist	14 (39%)	22 (61%)	
Orthodontist	53 (60%)	35 (40%)	
Years in Practice			0.1914
Less than 10 Years	17 (65%)	9 (35%)	
10 or More	50 (51%)	48 (49%)	
Invisalign Cases in Past 12 Months			0.0316
0-50	31 (48%)	34 (52%)	
51-100	10 (45%)	12 (55%)	
101+	25 (74%)	9 (26%)	
Percent Invisalign			0.3669
0-10%	18 (56%)	14 (44%)	
11-25%	16 (52%)	15 (48%)	
26-50%	16 (70%)	7 (30%)	
51-74%	5 (56%)	4 (44%)	
75-100%	11 (41%)	16 (59%)	

When respondents were able to select all methods that they used, the most commonly selected facial attachment for extruding maxillary lateral incisors was an optimized attachment (44%), followed by a gingivally beveled horizontal rectangular attachment (40%) and creating additional space around the tooth (37%) (**Table 4**). Many of the choices were significantly associated with provider type (**Table 5**). General dentists were significantly more likely than orthodontists to select an optimized attachment (69% vs 34%, p=0.0004) and what was suggested by the ClinCheck program (33% vs 10%, p=0.0029). Orthodontists were significantly more likely than general dentists to select a gingivally beveled horizontal rectangular attachment (51% vs 14%, p=0.0001) and creating additional space around the tooth (44% vs 17%, p=0.0039). Twelve orthodontists selected "other" and specifically indicated that they request a "sash attachment", and one additional orthodontist selected "other" and alluded to this attachment by design rather than name (14.44% of orthodontists). Three orthodontists specifically indicated that they would request

that the tooth be proclined to create interproximal space first, followed by simultaneous retraction and extrusion in a 1:1 ratio before closing the space.

Table 4: Facial Attachments Utilized for Extruding Maxillary Lateral Incisors.

Choice for Extruding Maxillary Lateral Incisors	n	%
Optimized Attachment	56	0.44
Gingivally Beveled Horizontal Rectangular Attachment	51	0.40
Additional space created around tooth	46	0.37
Horizontal Rectangular Attachment	31	0.25
Slow down aligner staging	36	0.29
Whatever ClinCheck suggests	21	0.17
Incisally Beveled Horizontal Rectangular Attachment	15	0.12
Fake Interproximal Reduction	3	0.02
Vertical Rectangular Attachment	2	0.02
No attachments/modifications requested	0	0.00

Table 5: Facial Attachments Utilized for Extruding Maxillary Lateral Incisors by Provider Type. Format of cell values is "n (%)".

Selections for Extruding Maxillary Lateral Incisors	General Dentist	Orthodontist	P-value
Optimized Attachment	25 (69%)	31 (34%)	0.0004
Gingivally Beveled Horizontal Rectangular Attachment	5 (14%)	46 (51%)	0.0001
Additional space created around tooth	6 (17%)	40 (44%)	0.0039
Horizontal Rectangular Attachment	8 (22%)	23 (26%)	0.6947
Slow down aligner staging	11 (31%)	25 (28%)	0.7552
Whatever ClinCheck suggests	12 (33%)	9 (10%)	0.0029
Incisally Beveled Horizontal Rectangular Attachment	3 (8%)	12 (13%)	0.5522
Fake Interproximal Reduction	0 (0%)	3 (3%)	0.5571
Vertical Rectangular Attachment	1 (3%)	1 (1%)	0.4914

When asked to specify which method was their most preferred, general dentists were significantly more likely than orthodontists to select an optimized attachment (50% vs 17%, p=0.0001) and orthodontists were significantly more likely than general dentists to indicate a gingivally beveled horizontal rectangular attachment (46% vs 3%, p<0.0001). None of the other selections demonstrated significant differences by provider type (Table 6).

Table 6: Most Preferred Facial Attachment for Extruding Maxillary Lateral Incisors by Provider Type. Format of cell values is "n (%)".

Preferred for Extruding Maxillary Lateral Incisors	General Dentist	Orthodontist	P-value
Optimized Attachment	18 (50%)	15 (17%)	0.0001
Gingivally Beveled Horizontal Rectangular Attachment	1 (3%)	41 (46%)	<0.0001
Additional space created around tooth	0 (0%)	6 (7%)	0.1816
Horizontal Rectangular Attachment	8 (22%)	11 (12%)	0.1745
Slow down aligner staging	1 (3%)	6 (7%)	0.6721
Whatever ClinCheck suggests	5 (14%)	8 (9%)	0.5171
Incisally Beveled Horizontal Rectangular Attachment	4 (11%)	10 (11%)	1
Fake Interproximal Reduction	0 (0%)	1 (1%)	1
Vertical Rectangular Attachment	1 (3%)	0 (0%)	0.2857

Only 7 respondents (5 orthodontists and 2 general dentists) indicated use of a palatal attachment (6%). Of those, 5 (71%) indicated they would use a horizontal rectangular attachment and one each selected a gingivally beveled horizontal rectangular attachment (14%) and a vertical rectangular attachment (14%).

Respondents were evenly distributed when asked what percent of their cases experienced an issue with tracking during lateral incisor extrusion, and these responses were not significantly associated with provider type (p=0.7628), number of Invisalign cases in the past 12 months (p=0.1905), or percent of orthodontic cases treated with Invisalign (p=0.1836). Overall, 19% indicated experiencing tracking issues in less than 25% of cases, 27% perceived tracking issues in 26-50% of cases, 28% perceived tracking issues in 51-75% of cases, and 26% indicated tracking issues in greater than 75% of cases. When asked what type of case presented the greatest likelihood of experiencing tracking issues, 44% (n=51) of respondents selected maxillary anterior crowding > 6 mm and 26% (n=30) selected anterior open bite (**Table 7**).

Table 7: Cases Indicated with Greatest Likelihood of Tracking Issues with Extruding Maxillary Lateral Incisors.

	n	%

Maxillary anterior crowding < 6 mm	18	0.16
Maxillary anterior crowding > 6 mm	51	0.44
Maxillary anterior spacing > 6 mm	2	0.02
Flared incisors (> 110 degrees)	4	0.03
Anterior open bite (canine to canine)	30	0.26
Class II division 1 correction	2	0.02
Class II division 2 correction	6	0.05
Class III correction	2	0.02

The majority of respondents indicated that when they determined that only a maxillary lateral incisor was not tracking, their first method of intervention was to take a refinement scan (n=78, 63%), and the second most common intervention was the bootstrap technique (n=24, 19%) (**Table 8**). These selections were not significantly associated with provider type (p=0.6426), years in practice (p=0.9086), number of Invisalign cases treated in the past 12 months (p=0.5670), or percent of orthodontic cases treated with Invisalign (p=0.1385). For those that intervened by taking a refinement scan, there were significant differences in timing of the scan based on provider type (p=0.0078). Orthodontists were more likely than general dentists to indicate waiting until the end of the series to take the refinement scan (63% vs 32%) whereas general dentists were more likely than orthodontists to indicate taking the refinement scan immediately (47% vs 13%) (**Table 9**).

Table 8: First Method of Intervention when Tracking Issues Present.

	n	%
Refinement scan	78	0.63
Bootstrap technique	24	0.19
Go back to the last aligner at which tooth was tracking	13	0.10
Add dimples to aligner	3	0.02
Other	6	0.05

Table 9: Timing of Refinement Scan. Format of cell values is "n (%)".

Timing	General Dentist	Orthodontist
Immediate	9 (47%)	7 (13%)

Next Visit	4 (21%)	12 (23%)
End of Series	6 (32%)	33 (63%)

To better assess the experience of doctors who treated a large number of aligner cases in their practices, a group of 33 "super users" was defined. These respondents were orthodontists who treated more than 100 cases with Invisalign in the past 12 months. Among these respondents, 48% used a gingivally beveled horizontal rectangular attachment, 39% used an optimized attachment, and 52% reported creating additional space around the tooth. When asked to specify their most preferred facial attachment, most indicated a gingivally beveled horizontal rectangular attachment (42%), followed by an optimized attachment (18%) (**Table 10**). An additional 5 respondents (15%) selected "Other" and wrote in the use of a "sash attachment". The perceived rate of issues with extrusion was less than 25% of cases for 36% of these respondents, but 16% of these "super users" perceived issues with extrusion in more than 75% of cases. The differences in perceived rates of issues were significantly different from "non-super-users", of whom 13% indicated experiencing tracking issues in less than 25% of cases and 30% indicated experiencing tracking issues in 75% or more of cases ($p=0.0287$). When intervention was deemed necessary, 70% indicated taking a refinement scan and 15% indicated using the bootstrap technique. For those who indicated a refinement scan, 52% would do it at the end of that series of aligners and 24% each selected immediately and at next visit. These intervention responses were not significantly different from those not deemed "super users."

Table 10: Facial Attachment Preferences for "super users". Format of cell values is "n (%)".

	Use	Preferred
Optimized Attachment	13 (39%)	6 (18%)
Gingivally Beveled Horizontal Rectangular Attachment	16 (48%)	14 (42%)
Additional space created around tooth	17 (52%)	4 (12%)
Horizontal Rectangular Attachment	8 (24%)	3 (9%)

Slow down aligner staging	6 (18%)	0 (0%)
Whatever ClinCheck suggests	3 (9%)	2 (6%)
Incisally Beveled Horizontal Rectangular Attachment	4 (12%)	2 (6%)
Fake Interproximal Reduction	2 (6%)	0 (0%)
Vertical Rectangular Attachment	0 (0%)	0 (0%)

Discussion

The results of this cross-sectional study indicate that despite improvements, both general dentists and orthodontists perceive the mean efficacy of aligners at performing extrusive movements of maxillary lateral incisors to be less than 50%. Clinicians who had treated over 100 cases with Invisalign in the past 12 months reported the highest perceived efficacy and those who had treated 50 or fewer cases in the past 12 months reported the lowest perceived efficacy. These data indicated that there was a slight increase in perceived efficacy with an increase in the number of cases treated. The data on when providers considered a maxillary lateral incisor to not be tracking and requiring intervention suggested that orthodontists are not only more critical of tooth position, but also of tracking issues.

There was no clear agreement between clinicians on percent of cases in which they experienced tracking issues when extruding maxillary lateral incisors. This finding seems to imply that though clinicians treating a larger number of cases with aligners have greater perception of their efficacy at extruding maxillary lateral incisors, that confidence does not necessarily translate to a better outcome. Respondents reported taking a refinement scan as the most common intervention when tracking issues were encountered, with a bootstrap elastic being the second most common intervention. The method of preferred intervention was not associated with provider type, years in practice, number of Invisalign cases in the past 12 months, or percentage of orthodontic cases treated with Invisalign. However, orthodontists were more likely to wait until the end of the

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series to take the refinement scan, whereas general dentists were more likely to scan immediately. Bootstrap mechanics typically involve removing any composite attachments from the tooth, cutting out the aligner and placing an attachment (hook, button, etc.) on the palatal surface of the tooth, and having the patient wear a small elastic from the palatal attachment over the incisal edge of the aligner to cutouts at the gingival margin of the facial surface of the aligner. Some clinicians choose to place attachments for elastics on both the facial and palatal surface of the tooth. The elastic places an extrusive force on the tooth and attempts to guide it into the aligner. This method of intervention is dependent upon patient compliance and acceptance of wearing an elastic that may be visible to others. A refinement scan requires less time to complete, however taking a refinement scan to address a single tooth early in the series of aligners may be considered inefficient by some clinicians due to the interruption of all tooth movements and time needed for laboratory turnaround. The difference between provider types with regard to timing of refinement scan may be related to orthodontists being more comfortable correcting tracking issues in a future series of aligners or a desire to avoid interruption of other simultaneous complex tooth movements (i.e. anteroposterior correction, vertical correction, general alignment, etc.) that may be occurring. The lack of difference between proportions of general dentists and orthodontists that intervene via the bootstrap technique is surprising and contrasts a previous reporting that general dentists use fewer auxiliary techniques than orthodontists.[26] Additionally surprising was that, among the respondents of this survey, the use of virtual monitoring was found to be similar between general dentists and orthodontists.

Acknowledging that clinicians may request more than just a specific attachment in their Clinchecks, respondents were asked to indicate all that they request when planning for extrusion of maxillary lateral incisors. The results indicated that general dentists were more likely to use an

optimized attachment and what was suggested by the ClinCheck program, whereas orthodontists were more likely to select a gingivally beveled horizontal rectangular attachment and creating additional space around the tooth. These results support a previous study that found general dentists spend less time modifying Clinchecks.[26] Additionally, it has been previously reported that creating interproximal space prior to simultaneously extruding and retracting the maxillary lateral incisor is important in achieving this movement.[16,17] The sash attachment, indicated by several respondents, is a gingivally beveled horizontal rectangular attachment rotated 45 degrees to cross the facial surface of the crown diagonally. This attachment design was popularized by Nicozisis for rotational correction of maxillary lateral incisors.[29,30] Boyd[15] recommended slowing down movements to less than the standard velocity per stage. We found that a third of the respondents selected this as a choice when able to select multiple answers. When asked to indicate a single preferred Clincheck request, general dentists most preferred an optimized attachment and orthodontists most preferred a gingivally beveled horizontal rectangular attachment. Due to the lack of high-quality controlled studies on this specific tooth movement with aligners, recommendations by those perceived as experts have great influence on clinicians, as demonstrated by our results. Based on the results of this survey, it would seem that orthodontists who are treating a large number of aligner cases per year tend to prefer a gingivally beveled horizontal rectangular attachment, create additional space around the tooth, and intervene when necessary by a refinement scan at the end of the series.

It is not surprising that, when asked what type of case presents the greatest likelihood of tracking issues with maxillary lateral incisors, respondents indicated maxillary anterior crowding > 6 mm, followed by anterior open bite (canine to canine). The third most common selection was maxillary anterior crowding < 6 mm (16%). It is possible that respondents that selected this answer

may choose to use another treatment modality for more complex cases or limit their aligner treatment to cases that fall in this category.

The perceptions identified in this study are consistent with the clinical findings of previous studies that indicated extrusion of maxillary lateral incisors with aligners is a challenging movement.[8,10,11,14] Our results are not consistent with the findings of Grunheid et al[12] and Charalampakis et al[13] who found extrusion of maxillary lateral incisors with Invisalign to be accurate. Both studies[12,13] had small samples sizes of mostly Class I patients, and patients in the study by Grunheid et al[12] had an average of only 2 mm of crowding in the maxillary arch. The perceived efficacy values found in our study are most similar to the findings of Haouili et al[14] who found an accuracy of 53.7% when extruding maxillary lateral incisors and attributed the improved accuracy from previous studies to be due to optimized extrusion attachments.

Notable limitations of this study included the restriction of respondents to a single choice when asked for their treatment planning preference for extruding maxillary lateral incisors with aligners, limiting respondents to a single choice of mid-course intervention, and a relatively small number of responses from general dentists. The results of this study support rejection of the null hypothesis.

Conclusion

1. The average perceived efficacy of aligners at extruding maxillary lateral incisors was 4.71 out of 10

2. Orthodontists were more likely to have a lower tolerance for tracking issues than general dentists (0.5 mm vs 1.0 mm, respectively)

3. The most common method of intervention when tracking issues were determined was a refinement scan timed differently for orthodontists (end of series) and general dentists (immediate)

4. When planning treatment, general dentists were significantly more likely to use an optimized attachment and what was suggested by the ClinCheck program, whereas orthodontists were significantly more likely to select a gingivally beveled horizontal rectangular attachment and creating additional space around the tooth

5. Cases with maxillary anterior crowding > 6 mm and anterior open bite are perceived to present the greatest likelihood of tracking issues

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