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Unplanned molar intrusion after Invisalign treatment

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Introduction: The objectives of this study were to analyze and quantify molar intrusion after the use of clear aligners and to analyze the relationship with other variables such as age, duration of treatment, and a series of cephalometric osseous and dental measurements at the start of treatment. **Methods:** A retrospective descriptive-analytical study was designed with a sample of 58 patients aged 18-60 years who had undergone treatment with Invisalign. The cephalometric measurements were carried out after lateral x-rays were taken of the cranium; these were compared at the start (T0) and conclusion of treatment. Parametric and nonparametric tests were used to compare means, whereas Pearson correlations and multivariate lineal regression analyses were used to establish the variables associated with molar intrusion. **Results:** Approximately 74.2% of the patients presented some degree of molar intrusion after treatment. Furthermore, 32.8% of patients presented intrusion only at the mandibular molar, whereas 25.9% experienced intrusion at both molars, maxillary and mandibular, simultaneously. However, 15.5% presented intrusion only at the maxillary molar. The average magnitude of intrusion here was 0.98 $\pm$ 0.54 mm, whereas the mandibular molar was 0.84 $\pm$ 0.29 mm. Statistically significant reductions exist for the distance L6_MP and U6_SN between T0 and at conclusion of treatment. Maxillary molar intrusion correlates negatively with mandibular molar intrusion ($r = -0.270$). The number of days of treatment did not correlate with either maxillary or mandibular molar intrusion. **Conclusions:** Clear aligners give rise to molar intrusion in 74.2% of patients. The cephalometric variables L6_MP T0, mandibular plane angle T0, and facial axis T0 were negatively and significantly associated with maxillary molar intrusion, whereas age and facial axis T0 were negatively associated with mandibular molar intrusion allowing smaller magnitudes of intrusion to be predicted when these variables present high values at T0. (Am J Orthod Dentofacial Orthop 2022;■:■-■)

In recent years, there has been a rise in the number of adult patients attending dental practices to request orthodontic corrections by way of invisible esthetic appliances such as lingual orthodontics or transparent aligners such as Invisalign.[1-4]

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Invisalign appliances appeared in 1997, but it was not until 1999 that they became available to orthodontists. The rationale of aligners was inspired in Kesling's positioner (1945)[4] and took advantage of advances in computer-aided design–computer-aided manufacturing technologies to manufacture the whole series of aligners without having to create a new setup for each of the movements programmed.[5]

The main advantage that Invisalign offers is its transparent and esthetic appearance, becoming the most popular choice for most of the adult population. Furthermore, the fact that it can be removed favors hygiene, and it has a higher tolerance rate in patients than other fixed-appliance options.[5]

The global increase in orthodontic treatments using clear aligners continues to be exponential. However, only scant solid literature is available regarding their in-depth biomechanical analysis and their effects on dentition.

A light posterior open bite is frequently observed in many patients wearing transparent aligners, a situation that is usually attributed to a possible molar intrusion.[5-8] This would be a consequence of the thickness of the said aligners and the number of hours the patient had been wearing them.[5] Some authors quantified this intrusion ranging from 0.25 to 0.5 mm, but no scientific evidence has supported these values.[5,7] Nonetheless, as there are no studies to confirm this, considerable controversy has escalated, and there are even some authors who go so far as to deny the said intrusion.[9] Furthermore, those studies that alluded to this phenomenon used EX30 (Align Technology, Santa Clara, Calif) material preceding the current SmartTrack (Align Technology). We are not aware of any study that has analyzed molar intrusion that may have arisen from using other materials before the appearance of SmartTrack, with which Invisalign manufactures aligners with a 0.75 mm thickness.

The objectives of this study were to determine the existence of molar intrusion after applying clear aligners; to quantify the said intrusion should it take place, and analyze the relationship with other variables: age of the patient, period of treatment (number of days), overbite, mandibular plane angle, occlusal plane angle, anterior facial height, inclination of the maxillary and mandibular incisive and extrusion of the maxillary and mandibular incisive.

MATERIAL AND METHODS

This retrospective and analytical-descriptive study complied with the Declaration of Helsinki for human research. The study protocol was approved by the Ethics Committee of the University of Valencia (Procedural Registration no. H1484756605438). All patients whose registers were used in this study were given detailed information beforehand, and informed consent was given before participating.

A sample size of 53 subjects was calculated; this figure is a sufficiently reliable number to obtain the mean molar intrusion, at a 95% confidence level and a precision range of ± 0.1 units, relative to values that are likely to have a standard deviation of approximately 0.35 units. The replacement rate was estimated to be 10%.

The following constituted the inclusion criteria: adult patients aged between 18 and 60 years that had finished the growth process (assessed on lateral cephalograms using the cervical vertebral maturation method),[10] with skeletal Class I, treated with Invisalign, availability of good quality lateral cephalogram with no left-right side evident superimpositions that could create doubts, photographs, and ClinChecks (Align Technology) at the starting and ending stages of treatment. All teeth had to have completely erupted, and the first and second permanent molars had to be present and in contact with their antagonists before, during, and after the treatment; these conditions had to be documented in photographs, as well as in ClinCheck.

The exclusion criteria were: patients with a deep overbite, patients with anterior open bite, patients who presented posterior open bite, before, during and/or after treatment, patients treated with measures to reduce posterior open bite (anterior bite bumpers, vertical elastics, or cutting out portions of the aligner to facilitate the extrusion), patients whose treatment plan (ClinCheck) included molar intrusion or distal movement of molars, patients wearing fixed prosthesis comprising >1 piece or prosthesis on osteointegrated implants. In addition, patients with an anchylosed tooth or exhibiting osseous support measuring less than half of the root or with signs or symptoms of active periodontal disease.

A consecutive sample of 58 patients was obtained; these patients had visited an orthodontic clinic to seek treatment between 2012 and 2018. The patients were treated with Invisalign and with material by SmartTrack. The patient participation rate in the study was 94%.

All patients were treated with clear aligners after the treatment had concluded and without posterior open bite, not detectable in photographic registers or ClinCheck. All photographic registers included occlusal imagery with the contact points marked with bite-articulation paper. All patients manifested posterior contacts in the occlusal photographs of all the intermediate phases of treatment. All the digital registries were made using the ITero intraoral scanner (Align Technology), revealing both initial and final occlusal contacts at each ClinCheck; this was the case for initial ClinCheck sessions and intermediate stages (additional aligners or refinements), whenever necessary.

With regard to the initial (T0) and final (T1) lateral cephalogram, 9 cephalometric points were identified, and 12 cephalometric skeletal and dental measurements were carried out manually by a sole observer with previous training in the procedure (Tables I and II; Figs 1 and 2).

Maxillary molar intrusion (mm) was calculated as the difference between U6_SN in T0 and T1 and mandibular molar intrusion (mm) as the difference between L6_MP in T0 and T1. The total molar intrusion (mm) was calculated as the sum of the maxillary and mandibular molar intrusion.

Before the start of the study, cephalometric measurements were carried out on 10 patients by the same observer (L.T.-G.) and then by a second researcher (M.A.P.-G.) (gold standard) to determine the intraobserver error (reproducibility) and interobserver error (validity).

Table I. Cephalometric hard tissue landmark abbreviations and definitions used in the study

	Landmark	Abbreviation	Definition
1	Sella	S	Point situated in the middle of the sella turcica
2	Nasion	N	The most anterior part of the frontonasal suture
3	Gnathion	Gn	The most anteroinferior point on the outline of the chin
4	Gonion	Go	The most posteroinferior point on the angle of the mandible
5	Menton	Me	The lowest most midline point on the mandibular symphysis
6	Anterior nasal spinal	ANS	The tip of the osseous anterior nasal spine
7	Posterior nasal spinal	PNS	The tip of the osseous posterior nasal spine
8	Basion	Ba	Most anterior point on foramen magnum
9	Pterygoid	PT	The intersection of the inferior border of the foramen rotundum with the posterior wall of the pterygomaxillary fissure

Statistical analysis

The data obtained for the cephalometric measurements were entered into an Excel spreadsheet (Microsoft, Redmond, Wash) and analyzed with SPSS (version 24.0; IBM, Armonk, NY).

Intraobserver and interobserver errors were calculated, taking into account coefficients of variation and Dahlberg's formula. The coefficient of variation is the relationship between the mean and standard deviation.

Descriptive analysis for mean, standard deviation, minimum, maximum, and median values and absolute and relative frequencies for the variable categories were carried out. The mean values obtained in the double measurement were analyzed using paired-sample t tests and intraclass correlation coefficient.

Normality was assessed using the Kolmogorov-Smirnov test. To analyze the differences between ≥2 means, the analysis of variance test was applied (or the nonparametric Kruskal-Wallis test). To analyze the differences between 2 means, the Student t test for paired measurements was used or the nonparametric Wilcoxon test.

Pearson parametric correlation coefficient or Spearman's nonparametric test was used to measure the linear association between age, duration of treatment, and the cephalometric measurements in T0 and T1 in consideration of the maxillary, mandibular, or total molar intrusion.

Multiple linear regression models were developed to determine the variables associated with the magnitude of maxillary, mandibular, or total molar intrusion produced. Logistic regression models were also applied to determine the association with the intrusion in the maxillary molar, mandibular molar, or both. The significance level was set at 5% ($\alpha = 0.05$).

RESULTS

Intraobserver error (reproducibility) and interobserver error (validity) were deemed acceptable as the Dahlberg values were <1 in the majority of dimensions; similarly, acceptability was enhanced by the coefficient of variation as values were <2.5%.

The sample size was 58 patients (38 women [65.5%] and 20 men [34.5%]). The mean age of the sample was 32.3 years, with a range of 18-60 years. The median age was 31 years. Only 2 patients were >46 years.

The mean treatment duration was 586.7 days, with a range of 126-1222 days; the median was 564.5 days.

When comparing the cephalometric measurements at T0 and T1, significant differences were only found in the distance L6_MP and U6_SN, which diminished from 72.1 to 71.8 mm and from 31.2 to 30.8 mm, respectively (Table III).

In 74.2% of patients (n = 43) molar intrusion was observed; however, in 15.5% (n = 9) molar intrusion occurred only in the maxillary molar. For 32.8% of patients (n = 19), molar intrusion occurred in the mandibular molar, whereas in 25.9% (n = 15), it occurred in maxillary and mandibular molars. Only 25.8% of patients did not present molar intrusion (Table IV).

The mean of intrusion in the maxillary molar was 0.28, whereas in the mandibular molar, it was 0.41 mm. When an intrusion is present in the maxillary molar, the mean was 0.98 mm; when present in the mandibular molar, it was 0.84 mm, and when an intrusion occurs in both molars, the value reached was 1.01 mm (Table IV). There were no significant differences (Kruskal-Wallis test, $P = 0.381$) between the intrusion mean values when comparing each other the groups only maxillary molar, only mandibular molar and both molars are involved. The linear correlation between maxillary and mandibular molar intrusion was negative ($r = -0.273$).

There were no significant differences with regard to gender after applying the Mann-Whitney U-test for maxillary molar intrusion ($P = 0.260$), mandibular molar intrusion ($P = 0.823$), or total molar intrusion ($P = 0.807$). In addition, there was no association (chi-square, $P = 0.092$) between gender and type of molar intrusion (maxillary, mandibular, or both).

Table II. Osseous and dental cephalometric measurements

	Landmark	*Abbreviation*	*Definition*
Osseous			
1	Mandibular plane angle (Steiner)	MP	Angular landmark; angle formed by the intersection of mandibular plane (Go-Gn) and SN; normal: 32° ± 4°
2	Occlusal plane angle (Steiner)	OP	Angular landmark; angle formed by the intersection of occlusal plane and SN; normal: 14° ± 2°
3	PP-MP angle	PP-MP	Angular landmark; angle formed by the intersection of PP and MP; normal: 22° ± 4°
4	Anterior facial height	AFH	Linear landmark; distance in mm between nasion and menton; normal 105-120 mm
5	Facial axis	FA	Angular landmark; angle formed by intersection of Ba-Na line and the facial axis from PT to Gn; normal: 90° ± 3.5°
Dental			
1	Overbite	OB	Linear landmark; distance in mm between maxillary and mandibular incisal edges perpendicular to the occlusal plane; normal: 2 mm
2	Mandibular incisor inclination	IMPA	Angular landmark; angle formed by the intersection of the mandibular incisor (A1) and mandibular plane (Me-Go); normal: 90° ± 2.5°
3	Maxillary incisor inclination (Burstone)	UII	Angular landmark; angle formed by the intersection of maxillary incisor (A1) and palatine plane (ANS-PNS); normal: 112°-117°
4	Mandibular molar position	L6_MP	Linear landmark; perpendicular distance in mm between mesiovestibular canine of mandibular first molar and mandibular plane (Go-Gn); no normal
5	Mandibular incisor extrusion	L1_MP	Linear landmark; perpendicular distance in mm between mandibular incisor edge and mandibular plane (Go-Gn); no normal
6	Maxillary molar position	U6_SN	Linear landmark; perpendicular distance in mm between mesiovestibular canine of maxillary first to sella-nasion plane (SN); no normal
7	Maxillary incisor extrusion	U1_SN	Linear landmark; perpendicular distance in mm between maxillary incisor edges to sella-nasion plane (SN); no normal

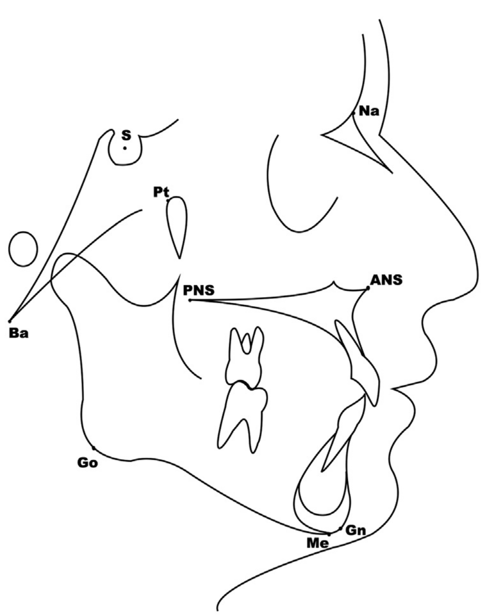

Fig 1. Illustration of the cephalometric landmarks used in the study.

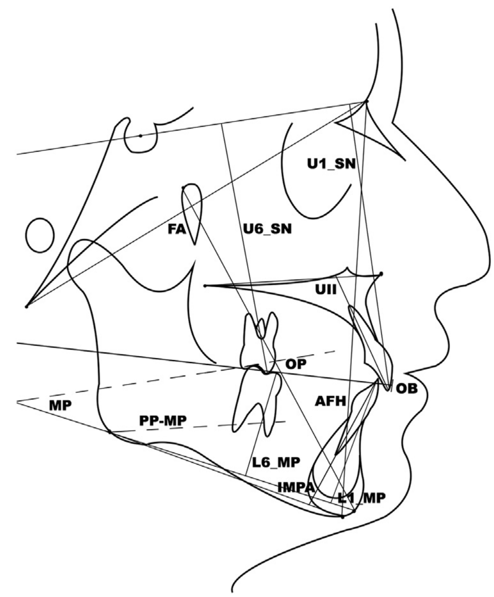

Fig 2. Illustration of the skeletal and dental measurements.

Table III. Cephalometric measurements (skeletal and dental) at T0 and T1

Variables	T0	T1	P value
Mandibular plane angle (MP), °	35.2 (33.5-35.9)	35.5 (33.8-37.2)	0.489‡
Occlusal plane angle (OP), °	18.6 (17.5-19.6)	18.2 (17.1-19.3)	0.220†
PP-MP angle, °	26.8 (25.2-28.3)	26.5 (24.9-28.1)	0.559‡
Anterior facial height (AFH), mm	122.1 (120.1-124.2)	122.4 (120.4-124.5)	0.244†
Facial axis (FA), mm	86.7 (85.5-87.9)	87.0 (85.8-88.2)	0.215†
Overbite (OB), mm	1.87 (1.31-2.44)	2.37 (2.10-2.64)	0.184‡
Maxillary incisor inclination (UII), °	109.7 (107.8-111.7)	108.5 (106.9-110.1)	0.172†
Mandibular incisor inclination (IMPA), °	93.3 (91.4-95.2)	94.1 (92.3-95.8)	0.473‡
Maxillary incisor extrusion (U1_SN), mm	81.1 (79.1-83.1)	81.2 (79.3-83.2)	0.548‡
Mandibular incisor extrusion (L1_SN), mm	39.0 (38.2-39.9)	39.1 (38.2-39.9)	0.981†
Maxillary molar intrusion (U6_SN), mm	31.2 (30.4-32.0)	30.8 (30.0-31.6)	<0.001†
Mandibular molar intrusion (L6_MP), mm	72.1 (70.9-73.3)	71.8 (70.6-73.1)	<0.001†

Note. Values are mean (95% confidence interval).
†Student *t* test;; ‡Wilcoxon test.

Table IV. Maxillary, mandibular, and total molar intrusion

Variables	With molar intrusion (n = 43)			Without intrusion (n = 15)	Total (n = 58)
	Only maxillary molar (n = 9)	Only mandibular molar (n = 19)	Both molars (n = 15)		
Maxillary molar intrusion	0.98 (0.56-1.39)	–	0.49 (0.42-0.56)	–	0.28 (0.17-0.39)
Mandibular molar intrusion	–	0.84 (0.70-0.98)	0.52 (0.41-0.64)	–	0.41 (0.30-0.52)
Total molar intrusion	0.98 (0.56-1.39)	0.84 (0.70-0.98)	1.01 (0.87-1.16)	–	0.69 (0.56-0.82)

Note. Values are mean (95% confidence interval).

Table V. Lineal correlations between cephalometric measurements at T0, age, and duration of treatment for maxillary, mandibular, or total molar intrusion

Variables	Maxillary molar intrusion, mm		Mandibular molar intrusion, mm		Total molar intrusion, mm	
	r	P value	r	P value	r	P value
Mandibular plane angle (MP), °	−0.268	0.042*	0.200	0.131	−0.058	0.663
Occlusal plane angle (OP), °	−0.278	0.035*	0.181	0.175	−0.083	0.538
PP-MP angle, °	−0.187	0.159	0.155	0.244	−0.028	0.834
Anterior facial height (AFH), mm	−0.106	0.431	0.087	0.515	−0.016	0.904
Facial axis (FA), mm	−0.001	0.993	−0.213	0.109	−0.177	0.185
Overbite (OB), mm	0.084	0.533	−0.139	0.298	−0.045	0.737
Maxillary incisor inclination (UII), °	0.102	0.447	0.061	0.651	0.135	0.312
Mandibular incisor inclination (IMPA), °	0.059	0.661	−0.010	0.938	0.040	0.763
Maxillary incisor extrusion (U1_SN), mm	−0.036	0.787	0.181	0.173	0.119	0.372
Mandibular incisor extrusion (L1_SN), mm	−0.153	0.253	0.165	0.216	0.009	0.947
Maxillary molar intrusion (U6_SN), mm	0.014	0.918	0.054	0.690	0.056	0.678
Mandibular molar intrusion (L6_MP), mm	−0.270	0.040*	0.055	0.682	−0.180	0.177
Age	0.141	0.291	−0.190	0.153	−0.039	0.770
Days of treatment	0.071	0.597	−0.103	0.442	−0.026	0.848

*Statistically significant.

Table V presents correlations between the cephalometric measurements at T0 and molar intrusion. The maxillary molar intrusion was negatively correlated with the mandibular plane angle ($r = -0.268$), occlusal plane angle ($r = -0.278$), and mandibular molar intrusion ($r = -0.270$). Neither age nor days of treatment were significantly correlated with molar intrusion.

Table VI. Lineal regression models for maxillary, mandibular, and total molar intrusion

Dependent variable	*Model*	*Predictive variables*	*Nonstandardized B coefficient*	*P value*
Maxillary molar intrusion	r^2 = 0.236 constant = 6.43 *P* = 0.002	L6_MP T0	−0.043 (−0.076 to −0.011)	0.010
		Mandibular plane angle T0	−0.036 (−0.058 to −0.014)	0.001
		Facial axis T0	−0.041 (−0.071 to −0.010)	0.010
Mandibular molar intrusion	r^2 = 0.111 constant = 3.01 *P* = 0.040	Facial axis T0	−0.025 (−0.049 to −0.002)	0.036
		Age	−0.012 (−0.025 to 0.000)	0.049
Total molar intrusion	r^2 = 0.16 constant = 7.60 *P* = 0.027	L6_MP T0	−0.041 (−0.082 to 0.000)	0.050
		Mandibular plane angle T0	−0.029 (−0.056 to −0.002)	0.035
		Facial axis T0	−0.053 (−0.091 to −0.015)	0.008

Using multivariate linear regression analysis, predictive models have been generated (Table VI). Thus, the magnitude of maxillary molar intrusion is significant and predictive in the model (r^2 = 0.236; P = 0.002): L6_MP T0, mandibular plane angle T0, and facial axis T0. Similarly, the mandibular molar intrusion is significant and predictive in the model (r^2 = 0.111; P = 0.040) concerning facial axis T0 and age. As predictive variable values increase, the molar intrusion tended to diminish after treatment in all models.

DISCUSSION

Cephalometric analysis has become a widely used method in evaluating molar intrusion and other skeletal and dental changes.[8,9,11-15] However, we believe that soon a protocol is likely to be developed to evaluate the molar intrusion occurring in wearers of transparent aligners; this is likely to be through cone-beam computed tomography (CBCT). This would offer us greater precision in measurement tasks and a 3-dimensional approach to what is happening in the molar. Limitations of lateral cephalograms are related to head positioning, movement during exposure, and magnification.[16] Despite these potential problems, lateral cephalograms are a valuable tool for measuring dental and skeletal parameters. Given that current radiation levels produced in a CBCT session are greater than in lateral cephalograms, we still have to leave aside this option.

The transparent aligners were changed every 7 days in all patients, a sufficient period to express the information given by each aligner[17,18]; nonetheless, other studies prescribed 15 days for each aligner.[5] It must be pointed out that the bibliography on the efficacy and indications of Invisalign is quite scant, and recently there have been great advances in the correction of complex cases; these advances include the design of more specialized attachments for rotations, radicular control, vertical movements, and so on.[19,20]

There are only 2 studies that offer cephalometric measurements to gauge molar intrusion after using clear aligners.[8,9] However, neither study used the current SmartTrack material. The present study analyzed the position of maxillary and mandibular molars by measuring the distance between maxillary first molar to SN plane and the distance between mandibular first molar to mandibular plane, respectively. By contrast, similar studies use the palatal plane to assess maxillary molar intrusion.[8,9] The authors of this work used SN and mandibular plane because they are stable and reproducible planes, as seen in other studies.[11] Palatal plane is less reliable because of its proximity to the intrusion area.[21]

According to our results, 74.2% of the patients presented molar intrusion; 15.5% of intrusion occurred only in the maxillary molar. In 32.8% of patients, intrusion occurred in the mandibular molar, whereas in 25.9% of patients, it occurred in both. The results are very similar to those obtained by Moshiri et al,[8] even though the material used in their study was not SmartTrack. However, Khosravi et al[9] did not observe any molar intrusion, although they did not exclude the patients who had been prescribed the use of virtual bite ramps. Virtual bite ramps help lessen the pressure exerted by the material between the occlusal surfaces, reducing posterior intrusion.

It has been observed that maxillary molar intrusion correlates negatively with the cephalometric variables: mandibular plane angle and occlusal plane angle; the smaller the value of these, the greater the probability of maxillary molar intrusion. Therefore, it is reasonable to suggest that this is due to the greater activity of the masseter muscle presented by patients with the brachycephalic biotype, followed by the mesocephalic biotypes;

this compares with dolichofacial patients who have the lowest molar intrusion rates.[22]

The cephalometric variables L6_MP T0, mandibular plane angle T0, and facial axis T0 were observed to be a predictor of maxillary molar intrusion, whereas the variable facial axis T0 predicts mandibular molar intrusion. In all models, when the values of the predictor variables increase, which will allow us to predict smaller magnitudes, in mm, of intrusion when these variables present high values at the start of treatment.

Furthermore, in patients with maxillary or mandibular molar intrusion, the occlusal plane angle and the anterior facial height decrease after treatment, as outlined in the results of the study by Moshiri et al.[8] It must also be stressed that no study exists in the literature that associates a given initial parameter of the patient with the intrusion produced at the end of treatment. None of the studied patients showed a significant change to the mandibular plane at the end of treatment, which is in accordance with the small amount of intrusion obtained.

Although molar intrusion was not prescribed in the treatment plan of the patients included in the sample, some of this effect was observed contrarily to the outcomes of treatments with conventional appliances, which usually cause a certain degree of molar extrusion.[23] In this study, adult patients were selected to avoid the possibility of dental growth distorting the results. Patients with fixed and implant-supported prostheses, dental anchyloses, or absences were discarded as they are conditions in which intrusion will be impeded or impossible. The authors confirmed the absence of growth in the sample by measuring mandibular length (Ar-Pg) and anterior facial height before and after treatment.[24]

We believe that molar intrusion is the result of the interposition of plastic material of the aligner during a semipermanent and prolonged period and occurring between the maxillary and mandibular occlusal surfaces, which in some patients with a certain degree of muscular strength (greater when the mandibular angle is comparatively small) produces a variable degree of molar intrusion. There are similarities with the effects of posterior build-ups in treatments with fixed appliances for open bite treatment as proposed by Vela-Hernández et al[11] because this study only included patients with a Class I profile in which no posterior intrusion or distal movement of molars were planned, we assume that any molar intrusion produced was due to the mentioned material interposition.

It has also been observed that the said molar intrusion is self-limiting as it usually involves a magnitude of 1 mm in both molars (ie, maxillary or mandibular). This may be explained as a neuromuscular adaptation by patients to recover their original vertical dimension, disrupted by continuous aligner use. Despite molar intrusion observed in the cephalometric analysis, all patients showed posterior occlusal contacts during treatment. This was assessed using articulating paper, which can help determine whether these contacts exist but are inaccurate to measure the occlusal force.[25,26] Future studies should quantify occlusal force using computerized occlusal analysis systems[27] and evaluate the correlation with molar intrusion.

It should be mentioned that the obtained intrusion could be transitory, so further studies would be needed to analyze possible cephalometric changes in this regard some months after treatment.

According to our results, there is no direct relationship between the duration of treatment and molar intrusion. In other words, it is not possible to affirm that with a longer period of treatment, there is a greater probability of intrusion, and further still, that intrusion will be greater should it occur. This may be explained by a muscular contraction stimulus favored by a slight increase in the vertical dimension because of transparent aligners[28]; The muscular stimulus may give way before the minimum period of prescribed treatment has elapsed. This study did not evaluate muscular stimulus. Further studies are needed to evaluate the correlation between the strength of the muscular contraction stimulus and molar intrusion. Functional magnetic resonance imaging can be used for this purpose.[29]

With regard to the limitations of this study, it should be noted that the sample of patients was consecutive (not randomly selected), and even though a sample size calculation was made, a larger sample would have permitted the analysis of subgroups. Although CBCT would have been more accurate to perform the measurements,[30] a 2-dimensional method, was used in this study because CBCTs just for the study were not considered justifiable. Furthermore, the age range in the sample has been slightly uneven, and we cannot ignore that the biology of dental movement can be conditioned by age. In addition, there are few scientific articles with an adequate methodology in this sphere. Three-dimensional technology in general and the field of transparent aligners and its materials, in particular, have undergone huge changes in a short time, meaning that scientific publications need to be constantly updated.

CONCLUSIONS

Based on our results with Invisalign (SmartTrack) treatment and within the limitations of this study, some findings can be summarized as follows:

1. A nonplanned molar intrusion of 0.94 mm was observed in 74.2% of the patients.
2. In 15.5% of patients, there was maxillary molar intrusion only, whereas, in 32.8% of patients, there was a mandibular molar intrusion only. In 25.9% of the patients, there was a molar intrusion in both arches.
3. There was no correlation between molars intrusion and treatment duration.

AUTHOR CREDIT STATEMENT

Laura Talens-Cogollos contributed to investigation, original draft preparation, and manuscript review and editing; Arturo Vela-Hernández contributed to investigation, supervision, and manuscript review and editing; María Aurora Peiró-Guijarro contributed to investigation and manuscript review and editing; Verónica García-Sanz contributed to investigation and manuscript review and editing; José María Montiel-Company contributed to methodology and manuscript review and editing; José Luis Gandía-Franco contributed to data curation and manuscript review and editing; Carlos Bellot-Arcís contributed to methodology, data curation, formal analysis, original draft preparation, and manuscript review and editing; Vanessa Paredes-Gallardo contributed to methodology, supervision, and manuscript review and editing.

REFERENCES

1. Ojima K, Dan C, Nishiyama R, Ohtsuka S, Schupp W. Accelerated extraction treatment with Invisalign. J Clin Orthod 2014;48:487-99.
2. Li W, Wang S, Zhang Y. The effectiveness of the Invisalign appliance in extraction cases using the the ABO model grading system: a multicenter randomized controlled trial. Int J Clin Exp Med 2015;8:8276-82.
3. Malik OH, McMullin A, Waring DT. Invisible orthodontics part 1: Invisalign. Dent Update 2013;40:203-4: 207-10, 213-204.
4. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. Angle Orthod 2015;85:881-9.
5. Phan X, Ling PH. Clinical limitations of Invisalign. J Can Dent Assoc 2007;73:263-6.
6. Boyd RL. Esthetic orthodontic treatment using the Invisalign appliance for moderate to complex malocclusions. J Dent Educ 2008;72:948-67.
7. Boyd RL, Miller RJ. The Invisalign system in adult orthodontics: mild crowding and space closure cases. J Clin Orthod 2000;34:203-12.
8. Moshiri S, Araújo EA, Mccray JF, Thiesen G, Kim KB. Cephalometric evaluation of adult anterior open bite non-extraction treatment with Invisalign. Dental Press J Orthod 2017;22:30-8.
9. Khosravi R, Cohanim B, Hujoel P, Daher S, Neal M, Liu W, et al. Management of overbite with the Invisalign appliance. Am J Orthod Dentofacial Orthop 2017;151:691-9.e2.
10. Franchi L, Baccetti T, McNamara JA Jr. Mandibular growth as related to cervical vertebral maturation and body height. Am J Orthod Dentofacial Orthop 2000;118:335-40.
11. Vela-Hernández A, López-García R, García-Sanz V, Paredes-Gallardo V, Lasagabaster-Latorre F. Nonsurgical treatment of skeletal anterior open bite in adult patients: posterior build-ups. Angle Orthod 2017;87:33-40.
12. Endo T, Kojima K, Kobayashi Y, Shimooka S. Cephalometric evaluation of anterior open-bite nonextraction treatment, using multiloop edgewise archwire therapy. Odontology 2006;94:51-8.
13. Carano A, Machata W, Siciliani G. Noncompliant treatment of skeletal open bite. Am J Orthod Dentofacial Orthop 2005;128:781-6.
14. Hart TR, Cousley RRJ, Fishman LS, Tallents RH. Dentoskeletal changes following mini-implant molar intrusion in anterior open bite patients. Angle Orthod 2015;85:941-8.
15. Erverdi N, Keles A, Nanda R. The use of skeletal anchorage in open bite treatment: a cephalometric evaluation. Angle Orthod 2004;74:381-90.
16. Houston WJ, Maher RE, McElroy D, Sherriff M. Sources of error in measurements from cephalometric radiographs. Eur J Orthod 1986;8:149-51.
17. Drake CT, McGorray SP, Dolce C, Nair M, Wheeler TT. Orthodontic tooth movement with clear aligners. ISRN Dent 2012;2012:657973.
18. Chisari JR, McGorray SP, Nair M, Wheeler TT. Variables affecting orthodontic tooth movement with clear aligners. Am J Orthod Dentofacial Orthop 2014;145(4 Suppl):S82-91.
19. Papadimitriou A, Mousoulea S, Gkantidis N, Kloukos D. Clinical effectiveness of Invisalign® orthodontic treatment: a systematic review. Prog Orthod 2018;19:37.
20. Cortona A, Rossini G, Parrini S, Deregibus A, Castroflorio T. Clear aligner orthodontic therapy of rotated mandibular round-shaped teeth: a finite element study. Angle Orthod 2020;90:247-54.
21. El Namrawy MM, Sharaby FE, Bushnak M. Intrusive arch versus miniscrew-supported intrusion for deep bite correction. Open Access Maced J Med Sci 2019;7:1841-6.
22. Gomes SGF, Custodio W, Jufer JSM, Del Bel CA, Garcia RCMR. Mastication, EMG activity and occlusal contact area in subjects with different facial types. Cranio 2010;28:274-9.
23. Pepicelli A, Woods M, Briggs C. The mandibular muscles and their importance in orthodontics: a contemporary review. Am J Orthod Dentofacial Orthop 2005;128:774-80.
24. Bishara SE, Treder JE, Jakobsen JR. Facial and dental changes in adulthood. Am J Orthod Dentofacial Orthop 1994;106:175-86.
25. Kerstein RB, Radke J. Clinician accuracy when subjectively interpreting articulating paper markings. Cranio 2014;32:13-23.
26. Sutter BA. A digital poll of dentists testing the accuracy of paper mark subjective interpretation. Cranio 2018;36:396-403.
27. Jeong MY, Lim YJ, Kim MJ, Kwon HB. Comparison of two computerized occlusal analysis systems for indicating occlusal contacts. J Adv Prosthodont 2020;12:49-54.
28. Widmer CG. The effects of altering vertical dimension on the masticatory muscles and temporomandibular joint. Semin Orthod 2002;8:155-61.
29. Bourdiol P, Hennequin M, Peyron MA, Woda A. Masticatory adaptation to occlusal changes. Front Physiol 2020;11:263.
30. Kosumarl W, Patanaporn V, Jotikasthira D, Janhom A. Distances from the root apices of posterior teeth to the maxillary sinus and mandibular canal in patients with skeletal open bite: a cone-beam computed tomography study. Imaging Sci Dent 2017;47:157-64.