Int. J. Morphol.,
40(4):920-926, 2022.

Morphology Changes of Maxillary Molar Distalization by Clear Aligner Therapy

Cambios de la Morfología en la Distalización de Molares Maxilares Mediante Terapia con Alineadores Transparentes

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CUI, J. Y.; TING, L. ; CAO, Y. X.; SUN, D. X.; BING, L. & WU, X. P. Morphology changes of maxillary molar distalization by clear aligner therapy. *Int. J. Morphol., 40(4)*:920-926, 2022.

SUMMARY: To evaluate the skeletal, dento-alveolar and soft tissue morphology changes after maxillary molar distalization by clear aligner therapy and identify the significant efficacy of molar distalization,18 patients in conformity with the inclusion criteria were selected. Pre- and post-treatment Cone Beam Computed Tomography (CBCT) were examined to measure the angular and linear parameters. All subjects were completed non-extraction clear aligner treatment by distalizing molars. A paired-t test and independent-samples t-test were performed to observe the difference between before and after treatment and the difference between the first molar and second molar respectively. P-values <0.05 were considered statistically significant. Predicted movement rate was calculated by the formula: (actual movement(mm)/planned movement(mm))×100%. Most variables of pre- and post-treatment showed no statistical difference($P<0.05$),excepting SNA angle ($P<0.05$) and Upper lip/E-line linear ($P<0.01$) due to incisor retraction. The first and second molar revealed a translation movement without significant tipping and vertical movement. Clear aligners provided a high predictability (83.44 %) of distalization the maxillary first molar, and 85.14 % of the maxillary second molar. Clear aligners can effectively achieve distal displacement of molars.

KEY WORDS: Morphological characteristics; Clear Aligners; molar distalization; Cone Beam Computed Tomography (CBCT).

INTRODUCTION

For patients with mild or moderate crowding or mild convex profile, clinicians may be more inclined to choose no-extraction orthodontics treatment, while one such effective method is molar distalization (Lai, 2019). Several conventional appliances such as headgear, pendulum, nickel-titanium coils enable efficient molar distalization (Lione *et al*., 2015; Abdelhady *et al*., 2020). But they have demonstrated side effects including crown rotation, mandible clockwise rotation due to fulcrum retrodisplacement and decreased overbite (Grec *et al*., 2013). In recent years, with the development of clear aligner orthodontic technology and its widespread clinical application, its significant advantages in molar distalization had been proved (Rossini *et al*., 2014). Aligners have a good control of vertical height because of the material covering and the long-term wear. Simultaneous generation of intrusion and distalization force enable effective tooth movement. Therefore, it is of great significance to further explore the efficiency of molar distalization by aligners. Cone-beam computed tomography CBCT accurately display craniomaxillofacial images from three dimensions with high resolution, which avoiding, compared to two-dimensional images, measurement errors caused by projection, magnification, overlapping images, etc. (Yusof *et al*., 2021). In this paper, position, angulation and root length of the maxillary first molar and central incisor pre- and post-treatment were measured and compared yield from CBCT to estimate the effectiveness of molar distalization and investigate the changes of tooth inclination, and soft tissue in the 3-dimensional space.

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Funding: Major international science and technology cooperation projects of Shanxi Province No. 201803D421062, No. 2015081030).
Scientific Research Fund for Returned Scholars of Shanxi Province . (No : HGKY2019-055).

Received: 2021-11-30 Accepted: 2022-05-24

MATERIAL AND METHOD

The sample size of this retrospective study was calculated using PASS software (version 15.0; NCSS Statistical Software, Kaysville, Utah). Based on prior literature which distalized molar with conventional appliances, with a value of 0.05 and b value of 0.1, the minimum required sample size is 13 patients. To intensify the credibility of the experimental context and compensate for possible dropouts, the records of 18 patients (mean age,27.8±5.38; range,18-38) treated with aligners in the Shanxi Medical University Hospital of Stomatology were included in this study, who were required to wear each aligner for 10 days for a minimum of 22 hours per day. The inclusion criteria were applied: (1) Class II malocclusions; (2) mild or moderate crowding; (3) congenitally missing or extracted third permanent molar; (4) completed non-extraction clear aligner treatment; (5) V pattern (Fig. 1) was adopted for bilaterally maxillary first molars distalization (6) the availability of per- and post-treatment CBCT of good quality depicting, which were performed with the same device (KaVo Dental GmbH, Germany). The data were exported to the DICOM format, and reconstructed into 3D craniomaxillofacial models by using the Invivo software (version 5.0, Anatomage, San Jose, Calif).

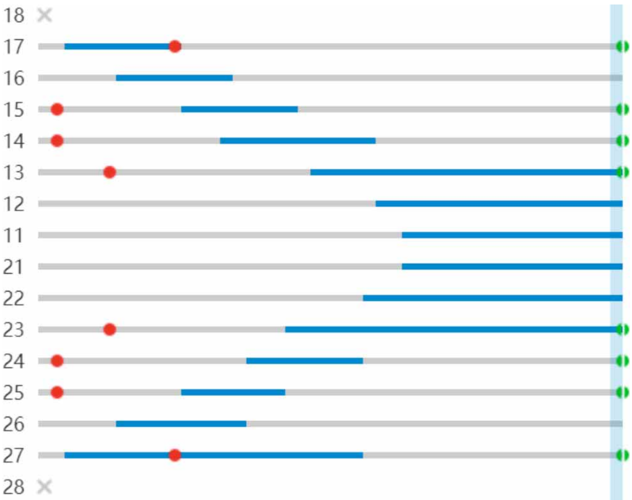

Fig. 1 the type of molar distalization: V pattern.

Three-dimensional Cephalometric Analysis. The horizontal linear measurements were based on the pterygoid vertical (PTV) plane, which is considered a stable reference plane in the sagittal direction (Enlow *et al*., 1971). The palatal plane (PP) was used as a reference plane for horizontal linear measurements of tooth movement, which connects the

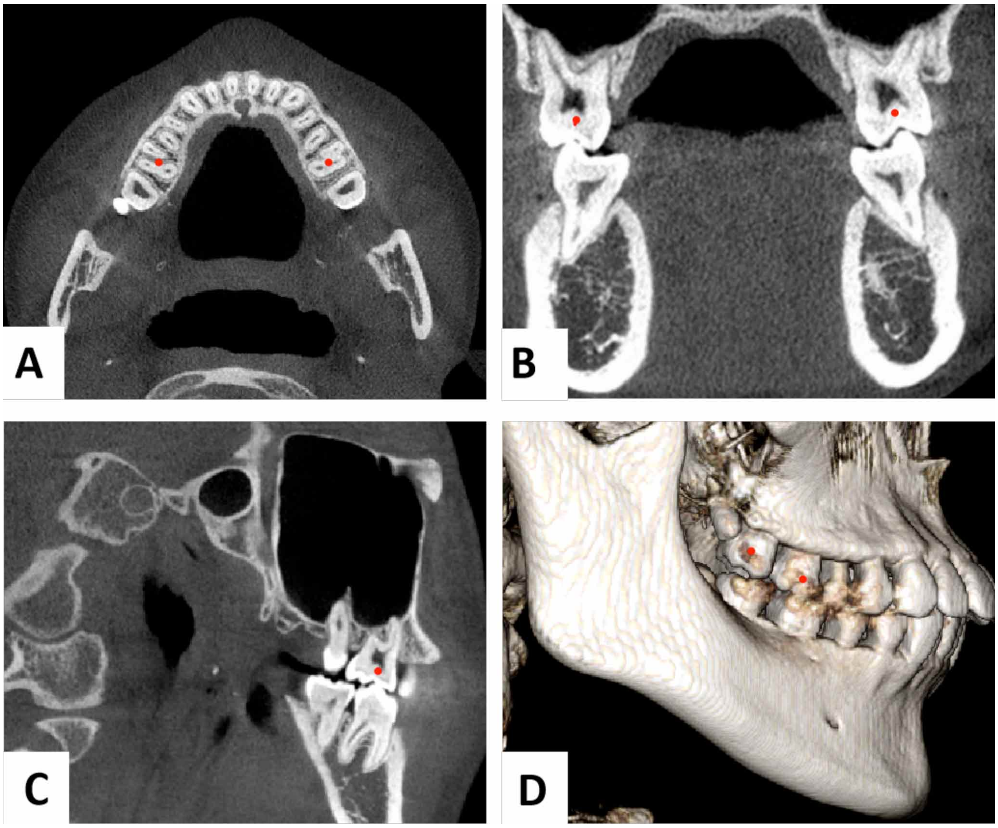

Fig. 2. Measuring points of maxillay molar. A. Horizontal axis plane view; B. Coronal plane view; C. Sagittal view; D. 3D view.

anterior and posterior nasal spine. The clinical crown center point for U6, U7 (Fig. 2) and incisal edge for U1 were used as landmarks. The vertical distance from each landmark to the reference plane was measured. The difference between the initial and final vertical distance was defined as the actual displacement of molar. The criteria for evaluating the efficacy of distalizing molars are: Predicted movement rate=(actual movement(mm)/planned movement(mm))×100 %. The data of planned movement was derived from patients' clincheck project and the actual movement was the difference of before and after treatment. The long axis of U6, U7 was defined as a line through the clinical crown center point and furcation point. Defining the line through incisal edge and root apex as the long axis of U1. Changes in position and axis of U6, U7 and U1and skeletal cephalometric parameters (Fig. 3) were measured. There are 19 variables to evaluated the changes of dentoalveolar and skeletal (Tables I and II). Eight measurements were used to assess skeletal changes and two measurements to assess soft tissue changes (Table I). Dentoalveolar measurements included three angular and six linear variables (Table II).

Statistical Analyses. Statistical analysis was performed using the computer program IBM SPSS Statistics (version 26.0; IBM, Armonk, N. Y). The normality assumption of the data was estimated with the Kolmogorov–Smirnov test. According to this evaluation, the differences between pre-treatment (T0) and post-treatment (T1) were compared with the paired-t test. Independent two-sample t-test was used to compare the differences between maxillary first and second molar measurements. The level of significance was set at P-values less than 5 %.

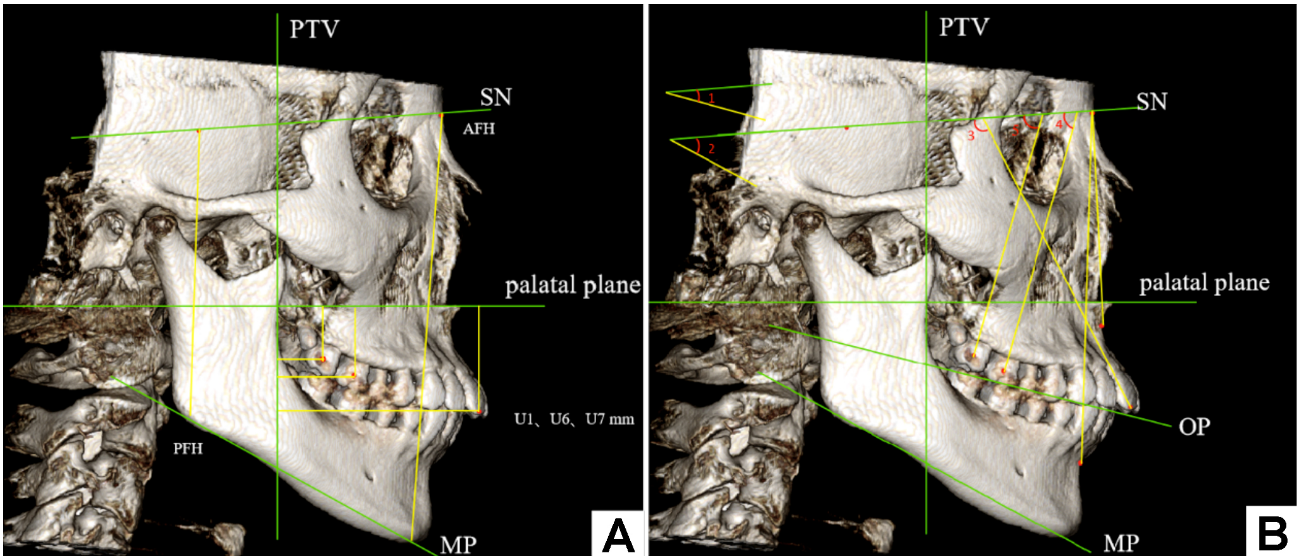

Fig.3 A: Linear measurement chart (sagittal and vertical distance). AFH, anterior facial height; PFH, posterior facial height; SN, sella-nasion plane; MP, mandibular plane; B: Angular measurement chart. 1.SN-OP; 2.SN-MP; 3.SN-U1; 4.SN-U6;5.SN-U7; SNA sella-nasion-A point; SNB, sella-nasion-B point; ANB A point-nasion-B point

Table I. Descriptive statistics of pre- (T0) and post-treatment (T1) measurements of skeletal and soft tissue measurements

	T0		T1		T1-T0		P value
	Mean	SD	Mean	SD	Mean	SD	
Skeletal measurements							
SNA(°)	80.39	0.68	80.17	0.62	-0.21	0.37	0.041
SNB(°)	76.16	0.49	76.15	0.55	0.01	0.10	0.693
ANB(°)	4.23	0.16	4.02	0.16	-0.20	0.38	0.167
SN-OP(°)	19.58	2.67	22.86	2.41	3.28	1.75	0.060
SN-MP(°)	34.70	5.16	34.92	6.01	0.22	0.73	0.572
AFH(mm)	112.03	4.96	111.75	4.28	-0.28	3.83	0.429
PFH(mm)	68.13	5.03	67.70	4.81	-0.43	2.95	0.437
PFH/AFH	0.63	0.02	0.65	0.04	0.02	0.01	0.525
Soft tissue							
Upper lip/E-line(mm)	0.25	2.17	-1.06	2.35	-1.31	1.06	0.006
Lower lip/E-line(mm)	1.64	2.76	1.48	2.69	-0.16	1.15	0.763

Table II. Three- dimensional movement measurements of U1, U6, U7.

	T0		T1		T1-T0		P value	Clincheck
	Mean	SD	Mean	SD	Mean	SD		
Dental angular								
U1/SN	105.43	3.74	98.39	4.05	-7.04	1.27	0.000	-8.25±1.04
U6/SN	75.73	2.94	72.30	3.87	-3.43	2.71	0.086	-2.93±2.10
U7/SN	80.18	3.82	75.84	2.92	-4.34	3.28	0.061	-3.84±2.41
Dental Linear measurements (mm)								
U1/PP	29.56	2.91	29.43	2.58	-0.13	1.73	0.623	-0.07±0.74
U1/PTV	54.36	4.27	52.96	3.92	-1.40	0.25	0.004	-1.61±0.57
U6/PP	20.04	1.94	18.84	2.06	-1.20	2.14	0.972	-0.26±0.63
U6/PTV	24.73	2.55	22.16	3.02	-2.57	1.15	0.000	-3.08±1.02
U7/PP	17.16	2.85	16.35	2.39	-0.81	2.51	0.326	-0.17±2.84
U7/PTV	14.42	3.04	11.44	2.46	-2.98	1.84	0.001	-3.50±2.97

RESULTS

The mean, standard deviation values of the change in skeletal and soft tissue are demonstrated in Table I. There was a significant difference in SNA angle (P<.05) and Upper lip/E-line linear (P<.01). PFH/AFH and SN-MP angle showed a decreasing tendency, but there was no statistical significance between two groups. No significant differences were detected in other variables (P<.05). Table II indicated the three- dimensional movement of incisor and molars. The distalization range of the U6 is 2.57±1.15mm (P<.01), and the U7 is 2.98±1. 84 mm (P<.01). Aligners provided a high predictability (83.44 %) distalization of U6, and 85.14 % of U7, without obvious vertical movement or tipping (P<.05). As we can see, the U1 moved significantly in a posterior direction with retraction by 1.40 mm (P<.01) and a decreasing of labial tipping (P<.01). Table III demonstrated that the two groups were statistically significant at the 0.05 level (bilateral) in vertical movements.

Fig. 4. Pre-treatment. A. Frontal, B. Profile photographs. Post-treatment. C. Frontal, D. profile photographs.

Table III. Independent t-test between planned and actual movements of U6 and U7.

	t	df	P value
Planned vertical movement	-.943	17	.475
Planned sagittal movement	-.497	17	.528
Planned sagittal angle	.315	17	.795
Actual vertical movement	3.548	17	.018
Actual sagittal movement	-.726	17	.487
Actual sagittal angle	-.391	17	.632

Typical cases. A 26-year-old woman who was diagnosed with Class II division 1 malocclusion and requested esthetic treatment. After 25 months of clear aligners treatment, the objectives had been achieved. The crowding was solved and the facial profile improved primarily by the maxillary molars distalization and the retraction of maxillary incisors (Figs. 4 and 5). The pre- and post-treatment lateral cephalometric analysis was compared, as shown in Fig. 6 and Table IV.

Fig.5. A. Pre-treatment intraoral photographs.
B. Post-treatment intraoral photographs.

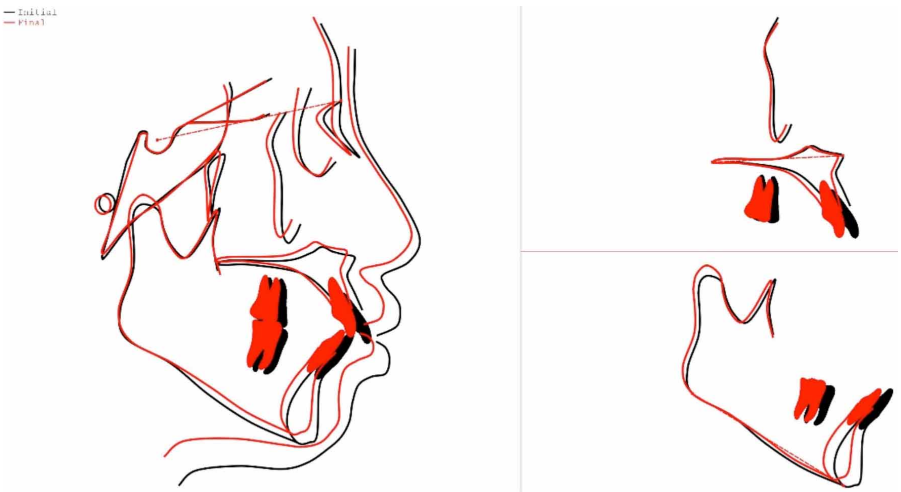

Fig. 6. Superimposition of pre- and post-treatment cephalometric tracings.

Table IV. Cephalometric Measurements at Pretreatment and Posttreatment.

Measurements	Norm	SD	Pretreatment	Posttreatment	Difference
Skeletal					
SNA	83	4	80	80.4	0.4
SNB	80	4	73.7	74.2	0.5
ANB	3	2	6.3	6.2	-0.1
SN-OP	19	4	19.5	21.7	2.2
SN-MP	30	6	42.2	42.2	0
FMA (FH-MP)	26	4	34.8	34.5	-0.3
Dentoalveolar					
U1-L1 (Interincisal Angle)	124	8	111.4	118.1	6.7
U1-SN	106	6	106	97.1	-8.9
U1-NA	23	5	26	16.7	-9.3
U1-NA (mm)	5	2	6.5	2.7	-3.8
L1-NB	30	6	36.3	39	2.7
L1-NB (mm)	7	2	10.1	8.9	-1.2
FMIA (L1-FH)	55	2	44.8	40.9	-3.9
Soft tissue					
LL-EP (mm)	1	2	5.8	3	-2.8
UL-EP (mm)	-1	1	2.3	1.6	-0.7

DISCUSSION

In this prospective study, evaluation of skeletal, soft tissue and dentoalveolar efficacy of aligners treatment in distalizing maxillary molars was achieved. Results indicate that a translation movement of molar without tipping and vertical movements can be realized at least when the minimal distance is required. Previous studies have described the distal displacement of molars. In the investigation carried out by Ravera *et al*. (2016), the average distal displacement of bilaterally maxillary first molars in the 20 adult patients were 2.25 mm and the maxillary second molars were 2.52 mm, which is general agreement with Simon's study that illustrated the distal displacement of 2~3 mm (Simon *et al*., 2014). If the distal displacement of the molars is beyond 4 mm, extraction of anterior molars is a more appropriate orthodontic treatment to correct malocclusion. Thus, before orthodontic treatment?careful indications selection is of major importance. It is essential to extract them, if there were upper third molars in patients' dentition, so that we can obtain enough room to move second and first molars in correcting class II malocclusions. CBCT (Cone beam computed tomography) is often required to measure the posterior clearance of the molar. Attachments also play an important role in the distalizing movement of the molar. Samoto & Vlaskalic (2014) proposed that the torque generated by the clear aligner is not sufficient to control the root movement of the tooth, so that a vertical rectangular attachment should be used to generate a force couple against the mesial tipping during the molar distalization. By *in vitro* study, Simon *et al*. (2014) accentuated that the mean accuracy supported with an attachment was 88.4 % (SD = 0.2), and without an attachment was 86.9 % (SD = 0.16). Furthermore, considering the reaction force comes primarily from molar movement, more anchorage control ,such as Class ?elastics and mini-screw anchored, can be optimized to achieve the optimal therapeutic efficacy without the increasing of incisor liable tipping and anchorage loss (Rossini *et al*., 2014; Bechtold *et al*., 2020).

In literature it was noted that extraoral and intraoral appliances caused side effects during the upper molars distalization procedure and on the sagittal vertical directions including clockwise rotation of the mandibular plane and decrease in the PFH/AFH ratio (Grec *et al*., 2013; Shpack *et al*., 2014). This would mean that hyperdivergent patient is a contraindication of the molar distalization. Results denoted that there were no changes in the divergence though observing variations of the change of SN-MP angle(P<.05) and no significant changes of the anterior and posterior facial height were revealed(P<.05). The present studies propose that clear aligners display a good control of mandibular divergence during molar distalization. These results are in keeping with what reported by Ravera *et al* (2016).

In this study, the actual sagittal movement of the maxillary second molars was greater than that of maxillary first molars,which is consistent with the results of Simon's study (Simon *et al*., 2014). The reason for this result may be that(1) Typically, the mechanical stimulus generated by aligners is distributed among the teeth, and throughout the periodontal ligament. The maxillary first molars' periodontal ligament area is usually larger than the maxillary second molars, and the need for support resistance during movement is greater. (2) the material of aligners is elastic, and when the number of distalizing tooth increases, the deformation produced by the aligners may increase, which would produce more three-dimensional directional changes undesirable.(3) the type of molar distalization in this study is V pattern, which means that the second molar has a separate distalization process, while the first molar movement is inevitably accompanied with the movement of other teeth. The amount of anchorage force during movement is different.

Clear aligners treatment is an effective orthodontic technique for distalizing maxillary molars, particularly suitable for adult patients who are require aesthetics. However, the effect of the molar distalization has a certain lag and needs to be considered by the orthodontist when designing the orthodontic plan to achieve the desired result.

CUI, J. Y.; TING, L. ; CAO, Y. X.; SUN, D. X.; BING, L. & WU, X. P. Cambios de la morfología en la distalización de molares maxilares mediante terapia con alineadores transparentes. *Int. J. Morphol., 40(4)*:920-926, 2022

RESUMEN: Se seleccionaron 18 pacientes, de acuerdo con los criterios de inclusión, para evaluar los cambios en la morfología esquelética, dentoalveolar y de los tejidos blandos después de la distalización de los molares maxilares, mediante la terapia con alineadores transparentes e así identificar la significativa eficacia de la distalización de los molares. Se examinó a través de tomografía computarizada de haz cónico (CBCT) antes y después del tratamiento para medir los parámetros angulares y lineales. Todos los sujetos completaron el tratamiento con alineadores transparentes sin extracción mediante la distalización de los molares. Se realizó una prueba t pareada y una prueba t de muestras independientes para observar la diferencia entre antes y después del tratamiento y la diferencia entre el primer molar y el segundo molar, respectivamente. Los valores de $p<0,05$ se consideraron estadísticamente significativos. La tasa de movimiento prevista se calculó mediante la fórmula: (movimiento real (mm)/movimiento planificado (mm)) × 100 %. La mayoría de las variables de pre y postratamiento no mostraron diferencia estadística ($P<0,05$), excepto el ángulo SNA ($P<0,05$) y el labio superior/línea E lineal ($P<0,01$) debido a la retracción del incisivo. El primer y segundo molar revelaron un movimiento de traslación sin inclinación significativa y movimiento vertical. Los alineadores transparentes proporcionaron una alta previsibilidad (83,44 %) de la distalización del primer molar superior y del 85,14 % del segundo molar superior. Los alineadores transparentes pueden lograr efectivamente el desplazamiento distal de los molares.

PALABRAS CLAVE: Características morfológicas; Alineadores transparentes; Distalización de molares; Tomografía computarizada de haz cónico (CBCT)

REFERENCES

Abdelhady, N. A.; Tawfik, M. A. & Hammad, S. M. Maxillary molar distalization in treatment of angle class II malocclusion growing patients: Uncontrolled clinical trial. *Int. Orthod., 18(1)*:96-104, 2020.

Bechtold, T. E.; Park, Y. C.; Kim, K. H.; Jung, H.; Kang, J. Y. & Choi, Y. J. Long-term stability of miniscrew anchored maxillary molar distalization in Class II treatment. *Angle Orthod., 90(3)*:362-8, 2020.

Bowman, S. J.; Celenza, F.; Sparaga, J.; Papadopoulos, M. A.; Ojima, K. & Lin, J. C. Creative adjuncts for clear aligners, part 1: Class II treatment. *J. Clin. Orthod., 49(2)*:83-94, 2015.

Enlow, D. H.; Kuroda, T. & Lewis, A. B. The morphological and morphogenetic basis for craniofacial form and pattern. *Angle Orthod., 41(3)*:161-88, 1971.

Grec, R. H. C.; Janson, G.; Branco, N. C.; Moura-Grec, P. G.; Patel, M. P. & Castanha Henriques, J. F. Intraoral distalizer effects with conventional and skeletal anchorage: a meta-analysis. *Am. J. Orthod. Dentofacial Orthop., 143(5)*:602-15, 2013.

Lai, W. Molar distalisation by using clear aligner treatment. *Int. J. Stomatol., 46(4)*:373-82, 2019.

Lione, R.; Franchi, L.; Laganà, G. & Cozza, P. Effects of cervical headgear and pendulum appliance on vertical dimension in growing subjects: a retrospective controlled clinical trial. *Eur. J. Orthod., 37(3)*:338-44, 2015.

Ravera, S.; Castroflorio, T.; Garino, F.; Daher, S.; Cugliari, G. & Deregibus, A. Maxillary molar distalization with aligners in adult patients: a multicenter retrospective study. *Prog. Orthod., 17(1)*:12, 2016.

Rossini, G.; Parrini, S.; Castroflorio, T.; Deregibus, A. & Debernardi, C. L. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. *Angle Orthod., 85(5)*:881-9, 2015.

Samoto, H. & Vlaskalic, V. A customized staging procedure to improve the predictability of space closure with sequential aligners. *J. Clin. Orthod., 48(6)*:359-67, 2014.

Shpack, N.; Brosh, T.; Mazor, Y.; Shapinko, Y.; Davidovitch, M.; Sarig, R.; Reimann, S.; Bourauel, C. & Vardimon, A. D. Long- and short-term effects of headgear traction with and without the maxillary second molars. *Am. J. Orthod. Dentofacial Orthop., 146(4)*:467-76, 2014.

Simon, M.; Keilig, L.; Schwarze, J.; Jung, B. A. & Bourauel, C. Forces and moments generated by removable thermoplastic aligners: incisor torque, premolar derotation, and molar distalization. *Am. J. Orthod. Dentofacial Orthop., 145(6)*:728-36, 2014.

Yusof, N. A. M.; Noor, E.; Reduwan, N. H. & Yusof, M. Y. P. M. Diagnostic accuracy of periapical radiograph, cone beam computed tomography, and intrasurgical linear measurement techniques for assessing furcation defects: a longitudinal randomised controlled trial. *Clin. Oral Investig., 25(3)*:923-32, 2021.

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