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Three dimensional assessment of the long-term treatment stability after maxillary first molar distalization with Carriere distalizer appliance

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Abstract: Introduction: Maxillary molar distalization is an efficient modality for treatment of dental Class II malocclusions in nongrowing patients. The long-standing maintenance of the results of the distalization therapy is a great challenge for orthodontists. **Aim:** The aim of this study was to assess the stability of the dental and the skeletal changes produced by the Carriere distalizer appliance followed by fixed appliance therapy 4 years after treatment using cone beam computerized tomography. **Materials and Methods:** This retrospective study involved randomly selected cone beam computerized tomographic images of 22 patients (15.9±2.4 years old) previously treated with Carriere distalizer appliance for maxillary molar distalization followed by fixed appliance therapy and retention period. Cone beam computerized tomographic images were taken before distalization (T1), after fixed orthodontic treatment (T2) and four years after treatment (T3) in the same standardized technique to assess the stability of dental and skeletal treatment results. **Results:** Between T2 and T1, maxillary first molar had significant distal movement (2.53±1.09 mm), intrusion (0.97±0.55 mm), and distal crown tipping (2.74°±1.1°) with insignificant rotation. Mandibular first molar showed significant mesial crown tipping (1.85°±0.87°), while lower incisors showed significant labial crown torquing (2.29°±1.17°). Between T3 and T2, the only significant dental effects were mesial crown tipping (1.01°±1.13°) of maxillary first molar with lingual crown torquing of lower incisors (1.08°±1.19°). SNA and ANB angles showed significant decreases (0.69°±0.48° and 1.16°±0.5° respectively), while SNB angle showed significant increase (0.47°±0.23°) between T2 and T1. There was significant decrease in ANB angle between T3 and T2 (0.5°±0.39°). **Conclusions:** Dental and skeletal treatment results of distalization accomplished with the Carriere Distalizer appliance followed by fixed appliance therapydisplayed minor changes 4 years after treatment.

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Keywords: Maxillary molar distalization; Class II malocclusion; Carriere Distalizer appliance; Cone beam computerized tomography.

1. Introduction

The long-standing maintenance of the results of orthodontic therapy is a great challenge for orthodontists[1]. Outcomes of orthodontic treatment are liable to significant changes that could jeopardize the long term stability of the occlusion[2]. Patients become satisfied not only if their occlusion is accepted at the end of the treatment, but also during the follow-up period[3].

Greco et al[4] reported that the extent of the unavoidable post treatment tooth movement varies depending on multiple factors that could be iatrogenic or innate to every patient and that the retention approaches that have been advanced to diminish post treatment movement do not ensure that the whole dentition could be retained in all directions. Relapse is frequently believed as an undesirable phenomenon, but certain dimensions of post treatment tooth movement might augment occlusal function and esthetics. Beneficial movement is commonly thought as ‘‘settling’’ if the occlusion is enhanced during the retention period[4].

Maximum undesirable tooth movements could evolve throughout the first two years after orthodontic therapy, decreasing after 4 years following finishing[4,5]. These movements could take place as a consequence to tension in periodontal ligament fibers, natural growth changes, alterations in the pressures originating from soft tissues and skeletal structures surrounding the teeth or improperly finished occlusion at the end of orthodontic treatment[6].

Dental Class II malocclusions in nongrowing patients could be treated by premolar extraction, intermaxillary elastics or maxillary molar distalization[7-11]. As all these approaches could provide the required over jet reduction, definite treatment considerations direct the operator to select the best modality[12,13].

The Carriere distalizer (Henry Schein Inc., New York, NY) is a simple fixed device that could be utilized for nonextraction Class II treatment by relocating the Class II buccal segment as one unit into a Class I occlusion[14]. It was designed to produce Class I molar and canine relationships, taking the anchorage from the lower arch[15,16]. As the initial distalization stage with the Carriere Distalizer appliance is usually ahead of the bonding of full edgewise appliances, the patient's compliance and general experience are at best[15-17]. The subsequent fixed appliance stage may be accompanied with orthodontic or orthopedic maxillary expansion to enhance and detail the occlusion[18].

No studies evaluated the stability of the results of maxillary molar distalization using Carriere distalizer appliance. Accordingly, the aim of this study was to assess the stability of the dental and the skeletal changes produced by the Carriere distalizer appliance 4 years after treatment. The null hypothesis was that the dental and skeletal changes produced by the Carriere distalizer appliance were not affected throughout a period of 4 years post treatment.

2. Materials and Methods

This retrospective study involved the cone beam computerized tomographic images of 22 patients (10 males and 12 females, with mean age of 15.9±2.4 year) who were previously treated by the same operator with Carriere distalizer appliance for maxillary molar distalization followed by fixed appliance therapy in the out-patient clinic of Orthodontic Department, Faculty of Dentistry, Minia University.

The criteria of selection included:

1- Bilateral Angle's Class II molar relationship, at least half cusp.

2- Skeletal Class I malocclusion (ANB angle ≤ 4 degrees).

3- Upper second molars were fully erupted before starting distalization.

4- No indication for extraction in the lower arch.

5- No history of preceding orthodontic treatment.

The ethical permission was approved by the ethical committee of the Faculty of Dentistry, Minia University. Sample size was established in accordance with Pandis[19], relying on a pilot study that comprised randomly selected CBCTs of 8 patients who were formerly treated with Carriere distalizer appliance for maxillary molar distalization. The effect size for the maxillary first molar distalization was 0.9 mm with a standard deviation of 0.95 mm. With a significance level of at 0.05 and a power of study 90%, the study included 22 patients.

At the end of maxillary molar distalization, every patient received a fixed orthodontic appliance phase followed by a retention period. Cone beam computerized tomographic images were taken before distalization (T1), after fixed orthodontic treatment (T2) and four years after the retention period (T3) in the same standardized technique.

Distalization protocol:

A 0.036" mandibular lingual holding arch was soldered bilaterally to mandibular first molar bands to supply anchorage for molar distalization. The mandibular teeth were bonded in all subjects by a single operator utilizing mini master brackets with 0.022" slot size (American Orthodontics, Sheboygan, Wis) and leveled to 0.019"×0.025" stainless steel arch wire to augment the anchorage. The Carriere distalizer appliance was then bilaterally bonded by the same operator for all patients (Figure 1).

Figure 1: Bonded Carriere distalizer appliance

Heavy Class II elastics with 1/4" diameter (American Orthodontics, Sheboygan, Wis) were attached from the mandibular molar band hook to the hook on maxillary cuspid pad of the distalizer. Patients were instructed to use the elastics permanently with the exception of eating or playing sports and substituting them after every meal.

Fixed orthodontic treatment:

When a Class I molar relationship was obtained, the distalizer was debonded and a Nance holding arch soldered to upper molar bands was fabricated and cemented. The upper arch was then bonded using mini master brackets with 0.022” slot size (American Orthodontics, Sheboygan, Wis) and the fixed orthodontic therapy was completed by the same operator.

Retention period:

After debonding of the upper and lower arches, removable Hawley retainers were fabricated for both arches and delivered to all patients. Patients were instructed to wear them in a full time manner except during eating for 1 year. This was combined with fixed mandibular canine-to-canine lingual retainers in all subjects.

Three dimensional cone beam computerized tomographic imaging, landmark identification and measurements:

Cone beam computerized tomographic images (Scanora3D, Sorredex- Finland) were taken at 15 mA and 85 KV before distalization (T1), after fixed orthodontic treatment (T2) and four years after the finishing the treatment (T3) in the same standardized technique. The attained CBCT images were transferred to DICOM format (Digital Imaging and Communications in Medicine) with the i-CAT software (Hatfield, Pennsylvania, USA). A completely reconstructed 3 dimensional image was produced by means of the Mimics image processing software (Materialise Group, Leuven, Belgium). Detection of landmarks was revealed by using the created multiplanar projections. The chosen points were then evaluated in the 3 dimensional images. Figure 2 and tables 1, 2 and 3 show the landmarks, planes and measurements used in this study.

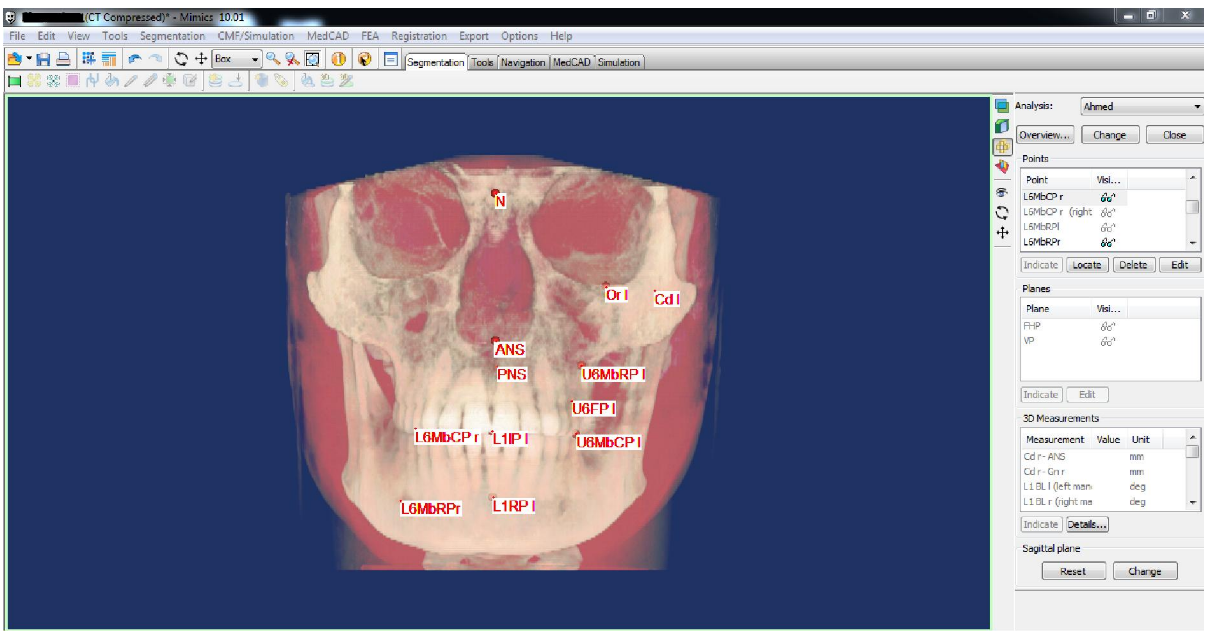

Figure 2: Identification of landmarks on the Mimics image processing software

Table 1: List of the 3-dimensional cephalometric reference points

Point	Description
S (Sella)	The central point of the sella turcica.
N (Nasion)	The anteriormost point on the frontonasal suture.
A (Subspinale)	The most concave midline point at the curved bony outline from the base to the alveolar process of the maxilla.
B (Supramentale)	The deepest point in the outer contour of the mandibular alveolar process in the median plane.
Or_R – Or_L (right and left orbitale)	The most inferior point on the orbital margin at both sides.
Po_R (right porion)	The uppermost point on the external auditory meatus on the right side.
ANS (anterior nasal spine)	The anteriormost midpoint of the anterior nasal spine of the maxilla.
PNS (posterior nasal spine)	The most posterior midpoint of the posterior nasal spine of the palatine bone.

Point	Description
Cd_R–Cd_L (right and left Condylion)	The highest point on the condylar head at both sides.
$U6MbCP_R$ – $U6MbCP_L$ (right and left maxillary first molar mesiobuccal cusp tip)	The tip of the mesiobuccal cusp of the maxillary first molar crowns at both sides.
$U6MbRP_R$ – $U6MbRP_L$ (right and left maxillary first molar mesiobuccal root apex)	The apex of the mesiobuccal root of the maxillary first molars at both sides.
$U6DbCP_R$ – $U6DbCP_L$ (right and left maxillary first molar disto-buccal cusp tip)	The tip of the distobuccal cusp of the maxillary first molar crowns at both sides.
$L6MbCP_R$ – $L6MbCP_L$ (right and left mandibular first molar mesiobuccal cusp tip)	The tip of the mesiobuccal cusp of the mandibular first molar crowns at both sides.
$U6FP_R$ – $U6FP_L$ (right and left maxillary first molar furcation point)	The mid furcation point among the roots of the maxillary first molars at both sides.
$L6MbRP_R$ – $L6MbRP_L$ (right and left mandibular first molar mesiobuccal root apex)	The apex of the mesiobuccal root of the mandibular first molars at both sides.
$L1IP_R$ – $L1IP_L$ (right and left mandibular central incisor incisal point)	The tip of the incisal edge of the right and left mandibular central incisor.
$L1RP_R$ – $L1RP_L$ (right and left mandibular central incisor root point)	The apex of the root of the right and left mandibular central incisor.

Table 2: List of the 3-dimensional cephalometric reference lines and planes

Line or plane	Description
FHP (Frankfurt horizontal plane)	The plane passing through Or_R, Or_L and Po_R points.
VP (Vertical plane)	The plane passing through Cd_R and Cd_L and perpendicular to the FHP.
MxS (Maxillary sagittal line)	The line connecting ANS and PNS.
FL (Frontal line)	The line connecting Or_R and Or_L.
U6 long axis	The line connecting U6MbCP and U6MbRP.
L6 long axis	The line connecting L6MbCP and L6MbRP.
L1 long axis	The line connecting L1IP and L1RP.

Table (3): List of the three-dimensional measurements

Measurement	Description
U6 AP (maxillary first molar antero-posterior position)	The perpendicular distance from ($U6MbCP_R$ or $U6MbCP_L$) to the VP (Vertical plane).
Maxillary first molar distalization	$U6\ AP_{Pre}$ - $U6\ AP_{Post}$
U6 VP (maxillary first molar vertical position)	The perpendicular distance from ($U6FP_R$ or $U6FP_L$) to the FHP (Frankfurt horizontal plane).
Maxillary first molar intrusion	$U6\ VP_{Pre}$ - $U6\ VP_{Post}$
U6 MD (maxillary first molar mesio-distal angulation)	The posterior angle between the U6 long axis and the MxS (Maxillary sagittal line).
U6 mesio-distal angulation change	$U6\ MD_{Pre}$ - $U6\ MD_{Post}$
U6 BL (maxillary first molar bucco-lingual inclination)	The external downward angle between the U6 long axis and the FL (Frontal line).
U6 bucco-lingual inclination change	$U6\ BL_{Post}$ - $U6\ BL_{Pre}$
U6 ROT (maxillary first molar rotation)	The internal angle between the line connecting the U6MbCP and U6DbCP and the MxS (Maxillary sagittal line).
Maxillary molar rotation	$U6\ ROT_{Pre}$ – $U6\ ROT_{Post}$
L6 AP (mandibular first molar antero-posterior position)	The perpendicular distance from ($L6MbCP_R$ or $L6MbCP_L$) to the VP (Vertical plane).
Mandibular molar mesialization	$L6\ AP_{Post}$ - $L6\ AP_{Pre}$
L6 MD (mandibular first molar mesio-distal angulation)	The posterior angle between the L6 long axis and the MxS (Maxillary sagittal line).
Mandibular molar mesio-distal angulation change	$L6\ MD_{Pre}$ - $L6\ MD_{Post}$
L1 BL (mandibular central incisor bucco-lingual inclination)	The anterior angle between the L1 long axis and the MxS (Maxillary sagittal line).
Mandibular incisor bucco-lingual inclination change	$L1\ BL_{Post}$ – $L1\ BL_{Pre}$
SNA	The angle between SN and NA lines
SNB	The angle between SN and NB lines
ANB	The angle between A,N and B points

Statistical method:

The resulting data were statistically analyzed using SPSS software (Version 9.0, SPSS, Chicago, USA). Descriptive statistics including means and standard deviations were calculated for every variable incorporated in this study.

Shapiro-Wilk test demonstrated normal distribution for all variables (P> 0.05 for all of them). Analyses were done using paired samples T-test to compare between the changes in all variables between T2-T1, T3-T1 and T3-T2. The level of significance was taken at P value < 0.05.

Error of the method

Data from CBCTs of 6 patients were retaken by the same operator after 3 weeks. Cronbach's Alpha was used to establish the reliability of the measurements.

3. Results:

Cronbach's Alpha was more than 0.9 for all measurements demonstrating excellent method reliability. The means and the standard deviations of the skeletal and dental variables at T1, T2 and T3 are presented in Table 4. Table 5 shows means, standard deviations and clinical significances of the measurements between T2 and T1, T3 and T1 and T3 and T2.

Table (4): Means and standard deviations of the skeletal and dental variables at T1, T2 and T3

	T1		T2		T3	
	mean	SD	mean	SD	mean	SD
U6 AP	60.6	2.4	58.1	2.3	58.5	2.4
U6 VP	33.3	2.3	32.5	2.2	33.4	2.3
U6 MD	85	2.6	81.2	2.4	83.7	2.7
U6 ROT	21.1	2.6	19.8	2.5	18.9	2.5
L6 AP	56.6	3	57.3	3	57	3
L6 MD	70.1	2.4	68.3	2.4	69.4	2.5
L1 BL	125.2	3.9	127.5	3.8	125.4	3.9
SNA	83.31	2.83	82.62	2.78	82.87	2.86
SNB	79.89	3.32	80.36	3.42	80.11	3.31
ANB	3.43	1.07	2.26	1.18	2.76	1.2

Table (5): means, standard deviations and clinical significances of the measurements between T2 and T1, T3 and T1 and T3 and T2

	T2-T1			T3-T1			T3-T2		
	Mean	SD	P value	Mean	SD	P value	Mean	SD	P value
U6 AP	-2.53	1.09	**0.031**	-2.29	1.08	**0.017**	0.23	0.3	0.751
U6 VP	-0.97	0.55	**0.04**	-0.76	0.4	0.182	0.21	0.49	0.089
U6 MD	-2.74	1.1	**0.001**	-1.72	1.37	**0.036**	1.01	1.13	**0.022**
U6 ROT	-1.33	0.35	0.082	-2.16	0.53	**0.021**	-0.83	0.42	0.478
L6 AP	0.73	0.46	0.549	0.44	0.33	0.314	-0.28	0.2	0.281
L6 MD	-1.85	0.87	**0.04**	-0.99	0.65	0.762	0.86	0.69	0.507
L1 BL	2.29	1.17	**<0.001**	1.21	0.51	**0.028**	-1.08	1.19	**0.036**
SNA	-0.69	0.48	**0.001**	-0.44	0.52	**0.045**	0.25	0.29	0.922
SNB	0.47	0.23	**0.026**	0.22	0.14	0.657	-0.24	0.18	0.568
ANB	-1.16	0.5	**<0.001**	-0.67	0.57	**0.003**	0.5	0.39	**0.042**

Between T2 and T1, the maxillary first molar had significant distal movement (2.53±1.09 mm), intrusion (0.97±0.55 mm), and distal crown tipping (2.74°±1.1°) with insignificant rotation. The mandibular first molar showed significant mesial crown tipping (1.85°±0.87°) with insignificant mesial movement. The lower incisors showed significant labial crown torquing (2.29°±1.17°).

Between T3 and T2, the only significant dental effects were mesial crown tipping (1.01°±1.13°) of the maxillary first molar with significant lingual crown torquing of the lower incisors (1.08°±1.19°).

The SNA and ANB angles showed significant decreases (0.69°±0.48° and 1.16°±0.5° respectively), while the SNB angle showed significant increase (0.47°±0.23°) between T2 and T1. There was significant decrease in the ANB angle between T3 and T2 (0.5°±0.39°), while SNA and SNB had insignificant changes.

4. Discussion:

The results of the distalization accomplished with the Carriere Distalizer appliance followed by fixed appliance therapy exhibited great stability with only limited changes at T3. In this study, Maxillary first molar was distalized 2.53±1.09 mm throughout the treatment stage (between T1 and T2), while it displayed 0.23±0.3 mm mesial movement throughout the period of four years after treatment (between T2 and T3). This could indicate that only 9.1% of the obtained distalization was lost during the long term follow-up period.

Shoaib et al[20] found that 12% of the achieved distalization was lost 3 years after finishing the treatment when modified C-palatal plates were used for molar distalization. This superior stability of the distal migration of the first molar was explained by the physical nature of the dental movement obtained with MCPPs[20]. According to Caprioglio et al[21], from 3.1 mm distalization at the end of the fixed appliance stage, only 0.2 mm of mesial movement wasidentified7 years following the finishing of orthodontic therapy, indicating absence of significant relapse in the post retention period. They stated that 91% of the relapse appeared during fixed appliance stage after molar distalization with the Pendulum appliance[21].

Melsen et al[22] assessed molar distalization with Kloehn headgear suggesting that during the 7-year post treatment period the distalized molar drifted sufficiently mesially to resume a site equivalent to that in the untreated patients. This was not attributed to the relapse of the Class I molar relation attained throughout treatment, but rather to the preservation of the anteroposterior molar relation through the more evident anterior growth in the mandible than in the maxilla[23]. Tortop et al[24] reported a significant mesial movement of the upper first molar throughout a period of 2 years following combined extraoral traction. However, this mesial movement did not result inalteration of molar relationship due to the mandibular anterior growth and the mesial displacement of the lower first molar.

Regarding maxillary first molar mesiodistal tipping in our study, the crown was tipped distally 2.74°±1.1° between T1 and T2. However, it was mesially tipped by 1.01°±1.13° between T2 and T3. 36.9% of the distal crown tipping occurring during the treatment period was corrected during the long term follow-up period. This was less than the 39.1% reported by Shoaib et al 3 years after treatment with modified C-palatal plates[20].

Caprioglio et al[21] identified 0.4° of mesial tipping 7 years following the finishing of orthodontic treatment. Tortop et al[24] reported that maxillary posterior teeth tended to restore their initial pretreatment angulations in the post treatment period.

Rocha et al[25] found that the distal tipping of the crowns of the maxillary first molars during distalization with the pendulum appliance followed by cervical headgear and fixed appliance therapy was lost 5 years after treatment. The mesial tipping during the post retention period could be attributed either to natural remaining growth or to dental relapse[25]. It was suggested that completely erupted permanent teeth could migrate as a component of normal craniofacial modifications at adulthood and that the horizontal component of force throughout mastication could result in mesial inclination of posterior teeth during adaptation to functional occlusal demands[26].

In this study, maxillary first molar intrusion was 0.97±0.55 mm between T1 and T2, while 0.21±0.49 mm extrusion was reported between T2 and T3. This suggests that 21.7% of the resulting intrusion was lost during the long term follow-up period. Shoaib et al[20] reported that 35% of the attained intrusion was relapsed during the post treatment period and this was explained by the lack of remaining growth to accommodate the post treatment extrusional changes as the patients were adults. Caprioglio et al[21] distinguished 0.4 mm of molar extrusion following completion of orthodontic treatment.

Mandibular first molar was mesialized (0.73±0.46 mm) and showed mesial crown tipping (1.85°±0.87°) between T2 and T1 in this study.38.4% of mesialization and 46.5% of mesial crown tipping was corrected during the four years post treatment period.

In our study, the lower incisors showed significant labial crown torquing (2.29°±1.17°) between T2 and T1 with significant lingual crown torquing (1.08°±1.19°) between T3 and T2. Ciger et al[27]reported that the lower incisors were proclined about 5° at the termination of treatment, and their inclination stayed relatively constant in the post retention period. Elms et al[28] reported that the lower incisors were slightly retroclined in the post retention period and this retroclination was inversely correlated with the extent of treatment change, with 0.2° of retroclination following treatment for every degree of proclination throughout treatment.

Regarding skeletal measurements in our study, there was significant decrease in the ANB angle between T3 and T2 (0.5°±0.39°), while SNA and SNB had insignificant changes. Bilbo et al[29] reported that distalization with high-pull face bow headgear followed by fixed edgewise treatment resulted in restriction of anteroposterior maxillary growth that was sustained during the retention period, no significant long-term influence on mandibular growth and long-term decrease in the ANB angle.

Ciger et al[27] found that only the SNB angle was significantly enlarged in the post retention period in patients treated with cervical headgear and full fixed orthodontic appliances as a result of the continuous mandibular growth. Tortop et al[24] reported that the significant reductions in SNA and ANB angles throughout the treatment period were maintained in the post-retention period. Although some studies proposed that after cessation of the forces, the maxilla could catch up on the restrained growth[23,30], the insignificant change of the SNA angle in the post retention period in our study does not agree with this claim.

Depending on cone beam computed tomography to evaluate the long term stability in this study was superior to the two dimensional cephalograms as the clarified landmarks in the traditional cephalometric radiographs are considered as 2D representations of 3D structures[31]. CBCT could introduce the significant advantage of one to one geometry and could afford the opportunity for identifying further anatomical landmarks that were not evident in the traditional cephalograms[32]. Furthermore, it was available to improve the efficacy of image utilization by eradicating the superimposition of anatomical parts that were not linked to the demanded landmark identification and three dimensional measurements[33].

Conclusion:

Dental and skeletal treatment results of distalization accomplished with the Carriere Distalizer appliance followed by fixed appliance the rap displayed minor changes 4 years after treatment.9.1% of the achieved maxillary first molar distalization, 21.7% of the intrusion and 36.9% of the distal crown tipping relapsed 4 years after treatment.

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