International Journal of Dentistry and Oral Science (IJDOS)
ISSN: 2377-8075

Effect of Fixed Orthodontic Therapy On The Condylar Position In Patients With Angle's Class I Malocclusions - A Retrospective Study

Research Article

Rajshekhar Banerjee[1], U.S. Krishna Nayak[2*], M.N. Kuttappa[3], M.S. Ravi[4]

[1] Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, A.B. Shetty Memorial Institute of Dental Sciences, Mangaluru, Karnataka – 575018, India.
[2] Principal and Dean, and Professor, Department of Orthodontics and Dentofacial Orthopaedics, A.B. Shetty Memorial Institute of Dental Sciences, Mangaluru, Karnataka – 575018, India.
[3] Professor, Department of Orthodontics and Dentofacial Orthopaedics, A.B. Shetty Memorial Institute of Dental Sciences, Mangaluru, Karnataka – 575018, India.
[4] Professor and Head of Department, Department of Orthodontics and Dentofacial Orthopaedics, A.B. Shetty Memorial Institute of Dental Sciences, Mangaluru, Karnataka – 575018, India.

Abstract

Introduction: Angle's class I malocclusions tend to consist of unstable dental relationships such as crowding, mal-positioned teeth, spacing, open bites, deep bites, and anterior and posterior crossbites. Correction of such malocclusions using fixed orthodontic therapy establishes a more stable occlusion and may result in a deflection in the position of the mandibular condyle. There has been limited research evaluating the effect fixed orthodontic therapy has on the position of the mandibular condyle.
Aims and Objectives: To investigate the effect of fixed orthodontic therapy on the position of the mandibular condyle, in patients with Angle's class I malocclusion.
Materials and Methods: Pre- and post-treatment digital lateral cephalometric images of 60 patients (35 female and 25 male) between the ages of 18-30, who had been treated for Angle's Class I malocclusion were selected for the study. The perpendicular distance of the condylion from the horizontal and vertical axes were measured in both the pre-and post-treatment lateral cephalogram of each patient. The change of position was calculated by comparing the pre- and post-treatment measurements in each axis.
Results: There was a statistically significant change in the position of the condyle in the horizontal axis, with the condyles positioned 0.297mm posteriorly post-treatment. The vertical change was insignificant. There were no statistically significant differences in the change in condylar position between males and females and among different subtypes of Angle's class I malocclusion.
Conclusion: Fixed orthodontic therapy in patients with Angle's Class I malocclusion resulted in a significant posterior shift in the condylar position post-treatment. This change is important as it can help the orthodontist predict the final post-treatment position of the condyle during orthodontic treatment planning.

Keywords: Condylar Position; Orthodontic Therapy; Class I Malocclusion.

Introduction

Among the several factors thatmay bring about an alteration in the morphology and position of the mandibular condyle,occlusal changes account for one of these. Orthodontic therapy with fixed applianceshas been likened by some authorsto a full-mouth prosthodontic rehabilitation in the way that it can amend the entire occlusion. Hence, the occlusal changes brought about by orthodontic therapy may result in a change in the position of the mandibular condyle. This position is also an important factor in the diagnosis and treatment planning in TMJ-oriented orthodontic therapy as previous studies have confirmed that different positions of the condyle in the glenoid fossa are related to various effects on the temporomandibular joint (TMJ) status.[1-3]

***Corresponding Author**:
U.S. Krishna Nayak,
Principal and Dean, and Professor, Department of Orthodontics and Dentofacial Orthopaedics, A.B. Shetty Memorial Institute of Dental Sciences, Mangaluru, Karnataka – 575018, India.
E-mail: druskrishnanayak@gmail.com

Received: April 02, 2021
Accepted: October 15, 2021
Published: October 25, 2021

Citation: Rajshekhar Banerjee, U.S. Krishna Nayak, M.N. Kuttappa, M.S. Ravi. Effect of Fixed Orthodontic Therapy On The Condylar Position In Patients With Angle's Class I Malocclusions - A Retrospective Study. *Int J Dentistry Oral Sci.* 2021;8(10):4829-4836. doi: http://dx.doi.org/10.19070/2377-8075-21000977

Angle's Class I malocclusions are frequently associated with dental crowding, spacing, rotations, malpositioned teeth, anterior open bites, deep bites, anterior and posterior crossbites. Malocclusions such as these have been reported to exhibit altered condylar positions.[4] Crowding and malpositioned teeth may cause occlusal interferences leading to the condyle not being seated in its proper position in relation to the glenoid fossa in centric relation.[5] Anterior open bites have been frequently reported to be associated with TMJ symptoms as well. This has been attributed by some authors to the lack of incisal guidance in anterior open bite malocclusions.[6] There has been some mention in literature implicating deep bites in potentially causing a disturbance in the condyle owing to the steep incisal guidance.[7] Unilateral posterior crossbites also exhibit a superior and posterior displacement of the crossbite side condyle accompanied by the movement of the contralateral condyle away from the glenoid fossa.[8, 9]

Fixed orthodontic treatment aims at eliminating occlusal discrepancies and achieving optimal occlusal contact of teeth. Hence, in the process of correcting the mentioned malocclusions, a change in position of the condyle may be predicted due to the establishment of a stable occlusion.

Although numerous studies have been done to evaluate the condylar position in Class II and Class III Malocclusions [10-12], very few have evaluated Class I malocclusions even though it is the most common malocclusion in the world. This is probably due to the aesthetic component being more severe in Class II and Class III malocclusions than in Class I malocclusions. There has also been very limited research assessing the effects of fixed orthodontic therapy on the position of the mandibular condyle.

Hence, this study was undertaken to investigate the positional changes of the mandibular condyle after preadjusted edgewise orthodontic appliance therapy in patients with Angle's Class I malocclusion.

Materials And Methods

The study was approved by the A.B. Shetty Memorial Institute of Dental Sciences (ABSMIDS) Ethical Committee (Certificate No. ABSM/EC52//2017). This retrospective study included 60 patients who had been diagnosed with Angle's class I malocclusion and treated with Pre-Adjusted Edgewise Fixed Orthodontic appliances at the Department of Orthodontics and Dentofacial Orthopaedics, ABSMIDS. The diagnosis had been performed with the aid of clinical examination, study models, photographs and digital lateral cephalograms, taken at the time of the patient's first visit. Patients between the ages of 18 to 30 years at the start of treatment were included to rule out positional changes of the condyle due to growth in younger patients and to rule out age-related degenerative condylar changes in older age groups. Patients with a history or diagnosis of any temporomandibular joint related diseases were excluded, as were patients with previous orthodontic or orthopaedic therapy, and orthognathic surgeries. Patients whose lateral cephalometric images were found to have unclear landmarks were also excluded.

Cases were selected by analysing completed cases of Angle's class I malocclusion treated in the department in reverse chronological fashion starting with the most recently finished case in July 2019. The first 60 cases which fit the inclusion and exclusion criteria were selected. Out of the selected patients, 35 were female and 25 were male. The selected patients were segregated into 7 subgroups, namely upper anterior proclination, bimaxillary protrusion, anterior crossbite, anterior open-bite, posterior crossbite, upper and lower anterior crowding and spacing. 35 of the selected cases had been treated with either 2 or 4 premolar extraction, while 25 had been treated without any extractions.

Pre- and post-treatment digital lateral cephalogram images of each patient were retrieved. Digital lateral skull radiographs were taken with Planmeca Promax® Cephalostat (Planmeca USA, Inc.) with exposure parameters of 68kV, 5mA, and 18.7 seconds. All lateral cephalometric tracings and measurements were performed by the same operator using the AudaxCeph Orthodontic Software Suite (Audax d.o.o., Ljubljana, Slovenia) cephalometric software.

Three points were marked on each lateral cephalogram image. (Figure 1)

i) T point: The superior most point in the anterior wall of the Sella Turcica situated at the junction with the Tuberculum Sella.[13]
ii) C point: The anterior-most point of the cribriform plate situated at its junction with the nasal bone. It is located on the cephalogram on the tip of the nasal bone.[13]
iii) Condylion (CO): The Posterosuperior most point on the curvature of the average of the right and left outlines of the condylar head.

Following this, two reference planes were drawn:

i) TC plane: Line drawn passing through the T point and C point.
ii) T vertical line: Line drawn perpendicular to the TC plane, passing through T Point.

The position of the condyle was assessed by measuring the perpendicular distances (in mm) between point CO and the TC plane and T-Vertical line as shown in Figure 1. The pre-and post-treatment measurements of CO to the TC plane distance was noted as CO-TC and CO-TC2, respectively,and CO to T Vertical Line distance was noted as CO-Tvert and CO-Tvert2, respectively. The difference between the pre- and post-treatment values would mark the change in condylar position in the horizontal and vertical axis. (Figure 2)

Analysis of the overall change in condylar position was done by Student's paired sample t-test. Paired-samples t-test was used to test the significance between the changes in males and females, and between extraction and non-extraction treatments. One-way ANOVA was used to calculate the level of significance for the changes among individual malocclusions. IBM SPSS Statistics software, version 21.0 was used to perform all statistical analyses. $P < 0.05$ was considered significant.

Results

In the present study, the subjects had an age range of 18-30 years with an average age of 21.98 ± 3.74 years. 35 were female (58.3%) and 25 were male (41.7%). 35 (58.3%) had been treated with either 2 or 4 premolar extractions, while 25 (41.7%) had been treat-

Figure 1. Linear Measurement of Condylar position.

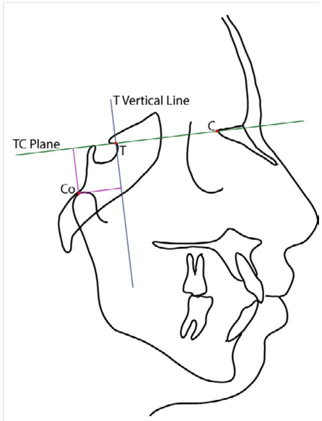
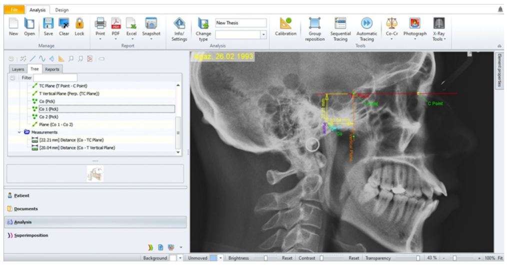


Figure 2. Measurements being recorded on a subject's Digital Lateral Cephalogram using Audax Ceph Orthodontic Software Suite (Audax d.o.oLjubjania, Slovenia).



ed without extractions.

Condylar Position

The mean pre- and post-treatment values for the CO-TC measurement were 20.6 mm and 20.56 mm respectively with a mean reduction of 0.035 mm (±1.183 mm). The CO-T vert measurement had a pre- and post-treatment means of 18.45 mm and 18.75 mm respectively, showing a mean increase of 0.297 mm (±1.057 mm). The CO-TC change was statistically insignificant. (p=0.819). However, the CO-Tvert measurement showed a significant increase (p=0.033). (Table 1)

Differences Between the Genders

There were 35 female subjects (58%) and 25 male subjects (42%) in the sample of this study. There were no statistically significant differences in the pre-treatment condylar positions between males and females, in either axis. (p > 0.05, p=0.418 and 0.326 for CO-TC and CO-Tvert respectively) The change in condylar position in both axes were statistically insignificant (p>0.05) in both male and female groups. Between the genders, there were no significant differences in the condylar position change in both axes between males and females. (Table 2)

Differences Between Extraction and Non-Extraction treatments

Individual samples t-test was performed to check the difference between extraction and non-extraction treatment. No statistically significant differences were observed in the position of the condyle in the extraction or non-extraction groups in either axis. There were no statistically significant differences between the groups either. (Table 3)

Differences Between different Skeletal Malocclusions

There was a statistically significant difference in the C-TC measurement between subjects with Class I and Class III skeletal relationship (p=0.048), while the difference in C-Tvert measurement was insignificant between these groups. No other statistically significant differences were found between either the C-TC or C-TVert measurements between Class I and Class II, and Class II and Class III subjects. There was no statistically significant difference between the groups either (p>0.05). (Table 4)

Individual Malocclusions

To check the variance among the changes seen in the various malocclusions present, one-way ANOVA was performed between the individual malocclusions. No significant differences in the changes in condylar positions were obtained for the changes of CO-TC and CO-Tvert. (p=1 and p=0.978 respectively) (Table 5).

Paired Samples t-test performed for the individual malocclusions showed that none of the malocclusions when taken individually had any significant changes in condylar position after being treated with pre-adjusted edgewise appliances. (Table 6)

Discussion

The effect of orthodontic therapy on the position of the condyles has been studied in the past by authors like Gianelly [14, 15], Hollender [3] and Khoo [16]. Gianelly and Hollender used a methodology which included comparing the anteroposterior position of the condyle of patients who had undergone orthodontic therapy with subjects who had not undergone any prior orthodontic treatment. Khoo tried to evaluate the same by measuring the distance of the condyle from a horizontal and vertical reference plane in both pre-and post-treatment lateral cephalograms of orthodontically treated patients and compared them to obtain the change in position. Our study followed a methodology similar to Khoo,

Table 1. Change in position of the Condyles in Vertical and Horizontal Axes.

Parameter	Pre-Treatment	Post-Treatment	Difference	Std. Deviation of the Difference	Paired Samples t-test Value	p-Value
C-TC	20.604	20.569	-0.035	1.183	0.23	0.819
C-Tvert	18.451	18.748	0.297	1.057	-2.179	0.033

Table 2. Difference in Condylar changes between Males and Females.

Parameter	Sex	N	Mean	Std. Deviation	Paired Samples t-test
C-TC Change	Male	25	0.166	1.236	1.118
	Female	35	-0.179	1.139	p = 0.268
C-Tvert Change	Male	25	0.386	1.049	0.546
	Female	35	0.234	1.074	p = 0.587

Table 3. Difference in Condylar changes between Extraction and non-extraction treatment plans.

Parameter	Treatment	N	Mean	Std. Deviation	t	p-value
C-TC Change	Extraction	35	0.242	1.248	1.552	0.126
	Non-Extraction	25	-0.233	1.109		
C-Tvert Change	Extraction	35	0.278	1.07	0.159	0.875
	Non-Extraction	25	0.323	1.063		

Table 4. Comparison of pre-treatment condylar position and change in condylar position in different skeletal relationships. (All measurements in mm).

Skeletal Relation	n	Mean pre-treatment C-TC measurement(in mm)	Mean pre-treatment C-Tvert measurement(in mm)	Paired t-test between C-TC measurements	Paired t-test between C-Tvert measurements	Mean C-TC change(in mm)	Mean C-TVert change(in mm)	Paired t-test between C-TC change	Paired t-test between C-Tvert change	One-way ANOVA (p-value)
Class I	32	21.31 (±3.31)	18.82 (±3.31)	p=0.460 (with Class II)	p=0.475 (with class II)	-0.16 (±1.11)	0.35 (±1.10)	p=0.985 (with Class II)	p=0.638 (with class II)	0.324 for C-TC change
				p=0.048 (with class III)	p=0.421 with Class III)			p=0.163 (with class III)	p=0.837 with Class III)	
Class II	15	20.52 (±3.66)	18.13 (±2.41)	p=0.460 (with Class I)	p=0.475 (with class I)	-0.15 (±1.10)	0.19 (±1.16)	p=0.985 (with Class I)	p=0.638 (with class I)	
				p=0.294 (with Class III)	p=0.855 (with Class III)			p=0.254 (with Class III)	p=0.813 (with Class III)	
Class III	13	18.96 (±4.01)	17.92 (±3.43)	p=0.048 (with class I)	p=0.421 with Class I)	0.40 (±1.42)	0.28 (±0.89)	p=0.163 (with class I)	p=0.837 with Class I)	0.885 for T-Tvert change
				p=0.294 (with Class II)	p=0.855 (with Class II)			p=0.254 (with Class II)	p=0.813 (with Class II)	

aiming at evaluating the effect fixed orthodontic treatment had on the condylar position in patients with Angle's Class I Malocclusion by evaluatingpre- and post-treatment lateral cephalograms of 60 patientsto ascertain the change in the position of the condyle.

In this study, the TC Plane was taken as the horizontal reference plane using the radiographic points of Point T and Point C, where Point T is the superior most point in the Sella Turcica's anterior wall where it forms a junction with the Tuberculum Sella, and Point C is the anterior-most point of the cribriform plate where it forms a junction with the nasal bone. The anterior wall of the Sella turcica and the cribriform plate stays unchanged after the age of first permanent tooth eruption. Hence, the TC plane would be of superior reliability than the SN plane which is subject to changes at later ages and shows a more anterior growth.[13] Although the present study was conducted on patients above the age of 18 years in whom growth would have ceased or would be minimal, the selection of the TC Plane ruled out errors in measurements

Table 5. Differences in Condylar Changes between individual Malocclusions.

Parameter	Malocclusion	N	Mean	Std. Deviation	Minimum	Maximum	ANOVA	p-Value
C-TC Change	Bimaxillary Protrusion	22	-0.055	1.287	-2.19	2.92	0.012	1
	Anterior Crossbite	6	-0.018	1.329	-2.29	1.54		
	Anterior Openbite	5	-0.018	1.462	-2.18	1.23		
	Posterior Crossbite	4	-0.135	0.541	-0.62	0.54		
	Upper and Lower Anterior Crowding	12	0.008	1.378	-1.87	2.48		
	Upper Anterior Proclination	8	0.009	0.886	-0.92	1.63		
	Anterior Spacing	3	-0.113	1.221	-1.49	0.84		
C-TVert Change	Bimaxillary Protrusion	22	0.31	1.241	-2.5	2.84	0.191	0.978
	Anterior Crossbite	6	0.58	1.301	-0.48	2.81		
	Anterior Openbite	5	0.27	0.542	-0.59	0.78		
	Posterior Crossbite	4	0.49	0.911	-0.68	1.54		
	Upper and Lower Anterior Crowding	12	0.167	1.263	-1.53	1.93		
	Upper Anterior Proclination	8	0.078	0.591	-0.59	1.21		
	Anterior Spacing	3	0.537	0.219	0.41	0.79		

Table 6. Change in Condylar positions for Individual Malocclusions.

Malocclusion		N	Mean	Std. Deviation	Mean Difference	Std. Deviation	Paired Samples t-Test	p-Value
Bimaxillary Protrusion	C-TC PreRX	22	21.645	3.109	0.054	1.287	0.199	0.844
	C-TC PostRX	22	21.591	3.438				
	C-TvertPreRx	22	18.022	3.648	-0.31	1.241	-1.172	0.254
	C-TvertPostRx	22	18.332	3.993				
Anterior Crossbite	C-TC PreRX	6	20.492	5.427	0.019	1.329	0.34	0.974
	C-TC PostRX	6	20.473	5.159				
	C-TvertPreRx	6	19.267	2.954	-0.58	1.301	1.092	0.325
	C-TvertPostRx	6	19.847	2.567				
Anterior Openbite	C-TC PreRX	5	18.602	3.351	0.018	1.462	0.028	0.979
	C-TC PostRX	5	18.584	2.617				
	C-TvertPreRx	5	20.608	2.183	-0.27	0.542	-1.113	0.328
	C-TvertPostRx	5	20.878	2.375				
Posterior Crossbite	C-TC PreRX	4	22.65	2.865	0.135	0.541	0.499	0.652
	C-TC PostRX	4	22.515	3.117				
	C-TvertPreRx	4	17.443	2.17	-0.49	0.911	-1.076	0.361
	C-TvertPostRx	4	17.933	1.646				
Upper and Lower Anterior Crowding	C-TC PreRX	12	19.887	3.651	-0.008	1.378	-0.21	0.984
	C-TC PostRX	12	19.895	3.636				
	C-TvertPreRx	12	19.263	2.508	-0.167	1.263	-0.457	0.657
	C-TvertPostRx	12	19.43	2.852				
Upper Anterior Proclination	C-TC PreRX	8	19.088	3.526	-0.008	0.886	-0.028	0.978
	C-TC PostRX	8	19.096	3.278				
	C-TvertPreRx	8	16.419	2.43	-0.077	0.591	-0.371	0.722
	C-TvertPostRx	8	16.496	2.564				
Anterior Spacing	C-TC PreRX	3	20.707	3.985	0.114	1.221	0.161	0.887
	C-TC PostRX	3	20.593	2.893				
	C-TvertPreRx	3	19.873	3.28	-0.537	0.219	-4.237	0.051
	C-TvertPostRx	3	20.41	3.063				

due to growth-related changes of the reference plane. The vertical reference line used was the T Vertical Line, which was drawn perpendicular to the TC Plane, passing through T point.

The present study found that the condyle moved by an average of 0.035 ± 1.183 mm towards the TC plane and an average of 0.297 ± 1.057 mm away from the TVert Plane. The vertical change in the condylar position towards the TC Plane was found to be insignificant with a p-value of 0.819 ($p>0.05$). However, the horizontal change in the position of the condyle away from the TVert Plane was found to be significant with a p-value of 0.033 ($p<0.05$). Hence, in the present study sample, the condyle was positioned significantly posteriorly after orthodontic treatment using pre-adjusted edgewise appliances in Angle's Class I Malocclusions. This is in contrast to the findings of a study by Khoo et al [16], which found that the condyle had no significant anteroposterior positional change, but did, however, find a significant change in position vertically. That study found that there was an inferior displacement in the condylar position in Angle's Class I malocclusions following Orthodontic treatment. Previous studies by Gianelly [10, 14, 15, 17] had found no significant changes in condylar position in patients who had undergone orthodontic therapy compared to untreated patients.

Farrar et al [18] and Hollender [3] had suggested that careless retraction of the anterior teeth post-extraction can cause the mandible to get locked into a posterior position, thereby causing the condyles to adopt a more posterior position. The present study did indeed find a posterior displacement in the condylar position, post-orthodontic treatment. In our study, 58.3% of the subjects had been treated with either two or four premolar extractions, while the rest had not undergone any extractions for their treatment. There was no statistically significant difference in the condylar position found after orthodontic treatment in patients who had undergone extractions. There were also no statistically significant differences in change in condylar position between patients who had undergone extractions and the ones who had not. Hence, in our study, there was no evidence found to support the theory that the mandible gets locked posteriorly due to excessive retraction.

A tendency of the condyles to be more anteriorly placed in subjects with Angle's Class I malocclusions was noted by Rodrigues [19] et al, Merigue [20]. Kikuchi [21] also reported a prevalence of anteriorly placed condyles in patients without any TMDs. Although the present study did not record the position of the condyle in relation to the glenoid fossa, the observed posterior shift of the condyle could be explained by anteriorly placed condyles assuming a more centric position in the mandibular fossa after the malocclusion is corrected.

A CBCT study by Miranda [22] observed that the condyle was more anteriorly placed in Skeletal Class II and Class III subjects than in Skeletal Class I subjects. Paknahad [23] also found skeletal Class II malocclusions having a more anteriorly placed condyle than Skeletal Class I and Class III. Kaur [24] conversely found that skeletal Class II malocclusions had a more posteriorly positioned condyle than Class I and Class III. Our study's resultsdisagreed with all these studies finding no statistically significant differences in the pre-treatment anteroposterior position of the condyle between any of the skeletal malocclusions. However, in the vertical axis,skeletal Class III subjects had their condyles positioned significantly superior to those with skeletal Class I relationship. No statistically significant differences were found between the change in position of the condyle between the different skeletal relationships.

The effect of maxillary expansion on the condylar position has had some controversy with studies getting conflicting results. A recent study by Melgaço et al [25] in 2014 found that in cases treated with Rapid Maxillary Expansion (RME), there was an anterior and inferior movement of the condyle post-treatment. This is in contrast to studies by Mcleod et al [26] and Leonardi et al [27], with both studies reporting no significant changes in condylar position post-treatment with RME. However, the effect of RME on the condylar position would have had minimal influence on the outcome of this study as only two subjects in the sample had been treated with RME.

Studies by Pullinger et al [28], Liu [29], and Akbulut [30] have reported significant differences in condylar position between males and females. Pullinger and Liu both found females to have more posteriorly placed condyles compared to males. Paknahad [31] also found females displaying a more posterior position of the condyles than males. However, this was only true among patients with TMD. Patients who showed no signs or symptoms of TMD had no significant difference in condylar position, according to gender. This is in accordance with the present study where the sample consisting of patients devoid of signs or symptoms of TMD, showed no significant differences in their pre-treatment condylar positions between males and females. There were no statistically significant differences between genders regarding the change in condylar position post orthodontic therapy either.

No statistically significant differences were found between the changes among the individual subtypes of Angle's Class I malocclusion. However, all the individual types showed a mean posterior deflection of the condyle post-treatment. Out of these, patients with anterior crossbites showed the maximum posterior displacement of 0.58 ± 1.3 mm, followed by anterior spacing (0.54 ± 0.22 mm), posterior crossbites (0.49 ± 0.91 mm), bimaxillary protrusion (0.31 ± 1.24 mm), anterior open bite (0.27 ± 0.54 mm), crowding (0.17 ± 1.26 mm) and upper anterior proclination (0.08 ± 0.6 mm). The correction of anterior crossbites involves establishing a positive overjet with the lower anterior teeth placed behind the uppers. This may cause a posterior shift of the mandible enabling it to be accommodated within the maxillary arch, thereby causing a posterior shift of the condyle. This finding is in agreement with the findings of Khoo et al[16] who also found a posterior displacement of the condyles in cases of anterior crossbites. The present study's observation regarding a posterior deflection of the condyle in patients treated for posterior crossbites is in agreement with the study done by Hesse [32] and in disagreement with the results of Lam [8] and Myers [33] who found no significant condylar position change; and Khoo who found an anterior displacement of the condyle. The posterior shift of the condyle in the cases of spacing can probably be attributed to the maxillary arch forcing the mandibular arch to shift backwards to be accommodated during closure of the anterior spaces.

There is some controversy that exists about the clinical significance of the condylar position in the TMJ. Hollender et al [3] found that the condyles were positioned more posteriorly in patients who suffered from clicking of the TMJ. Paknahad and

Shahidi [34] also concluded that posteriorly placed condyles were more prevalent in patients suffering from severe TMD's. Ikeda and Kawamura [35] found that the condyles are displaced more posteriorly in cases with disk displacements. Studies by Pullinger [2], Ren [36], Bonilla-Aragon [37], and Rammelsberg [38], all found posteriorly positioned condyles associated with disk displacement with reduction. Conversely, studies by Katzberg [39], Incesu [40], and Okur [41] found no discernible relationship between the two.

Furthermore, the correlation between condylar position and temporomandibular symptoms have been studied by numerous authors. Pereira [42], de Senna [43], and Okur [41] found no difference in the condylar position of patients with and without signs and symptoms of Temporomandibular disorder. On the other hand, Major [44], Gateno [45], Vasconcelos Filho [46], Huang and Zhang [47], and Cho and Jung [48] all observed a higher frequency of posteriorly positioned condyles in patients suffering from Temporomandibular disorders. Although the posterior positioning of the mandibular condyle's association with temporomandibular disorders and derangements is not absolute, there is strong evidence to suggest a correlation might exist.

The results of this study show that there is a net posterior shift in the condylar position post-orthodontic therapy. This is clinically significant as a more posterior position of the condyle post-treatment may increase the chances of TMDs developing. From the evidence available it cannot be satisfactorily concluded whether a posterior positioning of the condyle in the glenoid fossa causes temporomandibular disorders or whether TMD's themselves, cause the condyles to be positioned more posteriorly. Further research needs to be carried out to assess whether a posterior positioning of the condyle can subsequently develop into temporomandibular disorders.

A limitation of this study was that the condyle's relationship with the glenoid fossa was not explored. We could not assess whether the condyle shifted posteriorly in relation to the glenoid fossa or whether remodelling within the glenoid fossa forced the condyles posteriorly. Further studies should be undertaken to verify this.

Another limitation of this study was that the experiment was performed on lateral cephalograms of the subjects which only gives a 2-dimensional depiction of 3-dimensional structures. Conventional Tomography (CT) and Cone Beam Computed Tomography (CBCT) scans provide a comprehensive view of the mandibular condyles and generally would be the research medium of choice for condylar studies. However, since CT or CBCT imaging is usually done only or specifically indicated cases (in patients suffering from/suspected of TMDs, condylar erosions, ankylosis or neoplasms), obtaining pre- and post-treatment CT or CBCT images of 60 Angle's class I malocclusion patients who were devoid of temporomandibular symptoms was not found to be feasible for this study. Lateral cephalograms are routinely taken prior to starting orthodontic therapy and hence were chosen for the purposes of this study. Further prospective studies can utilize CT's and CBCT's to get a more detailed picture of the condylar changes, taking into consideration the ethical and radiation exposure issues.

Conclusion

In this retrospective study, a significant posterior displacement of the mandibular condyle was observed post-treatment, in patients with Angle's class I malocclusions treated with preadjusted edgewise appliances. Males and females showed no significant differences in their pre-treatment condylar position or in the change in their condylar position post orthodontic therapy.There was also no significant difference in the change in condylar position between patients treated with two or four premolar extractions and those treated without extractions. The individual malocclusion types of bimaxillary protrusion, anterior crossbite, anterior open-bite, posterior crossbite, anterior crowding, upper anterior proclination, and anterior spacing showed an insignificant but a net posterior displacement of the condyle post-treatment.

Acknoweldgements

I would like to acknowledge the contributions of Dr. Keerthan Shashidhar and Dr. Tanushree Jain for their help and inputs regarding the preparation of the manuscript.

References

[1]. Okeson JP. Evolution of occlusion and temporomandibular disorder in orthodontics: Past, present, and future. Am J Orthod Dentofacial Orthop. 2015 May;147(5 Suppl):S216-23. Pubmed PMID: 25925651.
[2]. Pullinger AG, Solberg WK, Hollender L, Guichet D. Tomographic analysis of mandibular condyle position in diagnostic subgroups of temporomandibular disorders. J Prosthet Dent. 1986 Jun;55(6):723-9. doi: 10.1016/0022-3913(86)90450-6. Pubmed PMID: 3459874.
[3]. Artun J, Hollender LG, Truelove EL. Relationship between orthodontic treatment, condylar position, and internal derangement in the temporomandibular joint. Am J Orthod Dentofacial Orthop. 1992 Jan;101(1):48-53. Pubmed PMID: 1731488.
[4]. Chokalingam S, AS F. Malocclusion and TMJ disease-A review of literature. IOSR JDMS. 2014;13(1):71-3.
[5]. Guttal SS, Nadiger RK, Suvarna A. A Comparison of the Change in Mandibular Condyle/Fossa Relationship with the Use of Anatomic Teeth and Semi-anatomic Teeth in Complete Denture Prosthesis. J Indian Prosthodont Soc. 2013 Jun;13(2):83-8. Pubmed PMID: 24431715.
[6]. Tanne K, Tanaka E, Sakuda M. Association between malocclusion and temporomandibular disorders in orthodontic patients before treatment. J Orofac Pain. 1993 Spring;7(2):156-62. Pubmed PMID: 8358361.
[7]. Thompson JR. Abnormal function of the temporomandibular joints and related musculature. Orthodontic implications. Part II. Angle Orthod. 1986 Jul;56(3):181-95. Pubmed PMID: 3461729.
[8]. Lam PH, Sadowsky C, Omerza F. Mandibular asymmetry and condylar position in children with unilateral posterior crossbite. Am J Orthod Dentofacial Orthop. 1999 May;115(5):569-75. Pubmed PMID: 10229892.
[9]. Andrade Ada S, Gameiro GH, Derossi M, Gavião MB. Posterior crossbite and functional changes. A systematic review. Angle Orthod. 2009 Mar;79(2):380-6. Pubmed PMID: 19216602.
[10]. Gianelly AA, Petras JC, Boffa J. Condylar position and Class II deep-bite, no-overjet malocclusions. Am J Orthod Dentofacial Orthop. 1989 Nov;96(5):428-32. Pubmed PMID: 2816843.
[11]. Seren E, Akan H, Toller MO, Akyar S. An evaluation of the condylar position of the temporomandibular joint by computerized tomography in Class III malocclusions: a preliminary study. Am J Orthod Dentofacial Orthop. 1994 May;105(5):483-8. Pubmed PMID: 8166098.
[12]. Rodrigues AF, Fraga MR, Vitral RW. Computed tomography evaluation of the temporomandibular joint in Class II Division 1 and Class III malocclusion patients: condylar symmetry and condyle-fossa relationship. Am J Orthod Dentofacial Orthop. 2009 Aug;136(2):199-206. Pubmed PMID: 19651349.
[13]. Viazis AD. The cranial base triangle. J Clin Orthod. 1991.
[14]. Gianelly AA, Hughes HM, Wohlgemuth P, Gildea G. Condylar position and extraction treatment. Am J Orthod Dentofacial Orthop. 1988 Mar;93(3):201-5. Pubmed PMID: 3422775.
[15]. Gianelly AA, Cozzani M, Boffa J. Condylar position and maxillary first premolar extraction. Am J Orthod Dentofacial Orthop. 1991 May;99(5):473-6. Pubmed PMID: 2028937.
[16]. Khoo JK, Bergman T, Avi L. Evaluation of changes in TMJ position for an-

gle class I malocclusion after orthodontic treatment by using cephalometric radiograph. UI Proceedings on Health and Medicine. 2017 Jan 3;1:58-62.
[17]. Gianelly AA, Anderson CK, Boffa J. Longitudinal evaluation of condylar position in extraction and nonextraction treatment. Am J Orthod Dentofacial Orthop. 1991 Nov;100(5):416-20. Pubmed PMID: 1951194.
[18]. Farrar WB. Differentiation of temporomandibular joint dysfunction to simplify treatment. J Prosthet Dent. 1972 Dec;28(6):629-36. Pubmed PMID: 4508486.
[19]. Rodrigues AF, Fraga MR, Vitral RW. Computed tomography evaluation of the temporomandibular joint in Class I malocclusion patients: condylar symmetry and condyle-fossa relationship. Am J Orthod Dentofacial Orthop. 2009 Aug;136(2):192-8. Pubmed PMID: 19651348.
[20]. Merigue LF, Conti AC, Oltramari-Navarro PV, Navarro Rde L, Almeida MR. Tomographic evaluation of the temporomandibular joint in malocclusion subjects: condylar morphology and position. Braz Oral Res. 2016;30:S1806-83242016000100222. Pubmed PMID: 26981751.
[21]. Kikuchi K, Takeuchi S, Tanaka E, Shibaguchi T, Tanne K. Association between condylar position, joint morphology and craniofacial morphology in orthodontic patients without temporomandibular joint disorders. J Oral Rehabil. 2003 Nov;30(11):1070-5. Pubmed PMID: 14641670.
[22]. Arieta-Miranda JM, Silva-Valencia M, Flores-Mir C, Paredes-Sampen NA, Arriola-Guillen LE. Spatial analysis of condyle position according to sagittal skeletal relationship, assessed by cone beam computed tomography. Prog Orthod. 2013 Oct 18;14:36. Pubmed PMID: 24325842.
[23]. Paknahad M, Shahidi S, Abbaszade H. Correlation between condylar position and different sagittal skeletal facial types. J Orofac Orthop. 2016 Sep;77(5):350-6. English. Pubmed PMID: 27357584.
[24]. Kaur A, Natt AS, Mehra SK, Maheshwari K, Singh G, Kaur A. Improved Visualization and Assessment of Condylar Position in the Glenoid Fossa for Different Occlusions: A CBCT Study. J Contemp Dent Pract. 2016 Aug 1;17(8):679-86. Pubmed PMID: 27659088.
[25]. Melgaço CA, Columbano Neto J, Jurach EM, Nojima Mda C, Nojima LI. Immediate changes in condylar position after rapid maxillary expansion. Am J Orthod Dentofacial Orthop. 2014 Jun;145(6):771-9. Pubmed PMID: 24880848.
[26]. McLeod L, Hernández IA, Heo G, Lagravère MO. Condylar positional changes in rapid maxillary expansion assessed with cone-beam computer tomography. Int Orthod. 2016 Sep;14(3):342-56. Pubmed PMID: 27542702.
[27]. Leonardi R, Caltabiano M, Cavallini C, Sicurezza E, Barbato E, Spampinato C, et al. Condyle fossa relationship associated with functional posterior crossbite, before and after rapid maxillary expansion. Angle Orthod. 2012 Nov;82(6):1040-6. Pubmed PMID: 22519882.
[28]. Pullinger AG, Solberg WK, Hollender L, Petersson A. Relationship of mandibular condylar position to dental occlusion factors in an asymptomatic population. Am J Orthod Dentofacial Orthop. 1987 Mar;91(3):200-6. Pubmed PMID: 3469906.
[29]. Liu Q, Wei X, Guan J, Wang R, Zou D, Yu L. Assessment of condylar morphology and position using MSCT in an Asian population. Clin Oral Investig. 2018 Sep;22(7):2653-2661. Pubmed PMID: 29388022.
[30]. Akbulut A, Kılınç DD. Evaluation of condyle position in patients with Angle Class I, II, and III malocclusion using cone-beam computed tomography panoramic reconstructions. Oral Radiol. 2019 Jan;35(1):43-50. Pubmed PMID: 30484184.
[31]. Paknahad M, Shahidi S, Iranpour S, Mirhadi S, Paknahad M. Cone-Beam Computed Tomographic Assessment of Mandibular Condylar Position in Patients with Temporomandibular Joint Dysfunction and in Healthy Subjects. Int J Dent. 2015;2015:301796. Pubmed PMID: 26681944.
[32]. Hesse KL, Artun J, Joondeph DR, Kennedy DB. Changes in condylar postition and occlusion associated with maxillary expansion for correction of functional unilateral posterior crossbite. Am J Orthod Dentofacial Orthop. 1997 Apr;111(4):410-8. Pubmed PMID: 9109586.
[33]. Myers DR, Barenie JT, Bell RA, Williamson EH. Condylar position in children with functional posterior crossbites: before and after crossbite correction. Pediatr Dent. 1980 Sep;2(3):190-4. Pubmed PMID: 6938933.
[34]. Paknahad M, Shahidi S. Association between mandibular condylar position and clinical dysfunction index. J Craniomaxillofac Surg. 2015 May;43(4):432-6. Pubmed PMID: 25770652.
[35]. Ikeda K, Kawamura A. Disc displacement and changes in condylar position. Dentomaxillofac Radiol. 2013;42(3):84227642. Pubmed PMID: 22933537.
[36]. Ren YF, Isberg A, Westesson PL. Condyle position in the temporomandibular joint: comparison between asymptomatic volunteers with normal disk position and patients with disk displacement. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 1995 Jul 1;80(1):101-7.
[37]. Bonilla-Aragon H, Tallents RH, Katzberg RW, Kyrkanides S, Moss ME. Condyle position as a predictor of temporomandibular joint internal derangement. J Prosthet Dent. 1999 Aug;82(2):205-8. Pubmed PMID: 10424985.
[38]. Rammelsberg P, Jäger L, Duc JM. Magnetic resonance imaging-based joint space measurements in temporomandibular joints with disk displacements and in controls. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000 Aug;90(2):240-8. Pubmed PMID: 10936845.
[39]. Katzberg RW, Keith DA, Ten Eick WR, Guralnick WC. Internal derangements of the temporomandibular joint: an assessment of condylar position in centric occlusion. J Prosthet Dent. 1983 Feb;49(2):250-4. Pubmed PMID: 6572265.
[40]. Incesu L, Taşkaya-Yilmaz N, Oğütcen-Toller M, Uzun E. Relationship of condylar position to disc position and morphology. Eur J Radiol. 2004 Sep;51(3):269-73. Pubmed PMID: 15294336.
[41]. Okur A, Ozkiris M, Kapusuz Z, Karaçavus S, Saydam L. Characteristics of articular fossa and condyle in patients with temporomandibular joint complaint. Eur Rev Med Pharmacol Sci. 2012 Dec;16(15):2131-5. Pubmed PMID: 23280030.
[42]. Pereira LJ, Gavião MB, Bonjardim LR, Castelo PM. Ultrasound and tomographic evaluation of temporomandibular joints in adolescents with and without signs and symptoms of temporomandibular disorders: a pilot study. Dentomaxillofac Radiol. 2007 Oct;36(7):402-8. Pubmed PMID: 17881599.
[43]. Robinson de Senna B, Marques LS, França JP, Ramos-Jorge ML, Pereira LJ. Condyle-disk-fossa position and relationship to clinical signs and symptoms of temporomandibular disorders in women. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009 Sep;108(3):e117-24. Pubmed PMID: 19716481.
[44]. Major PW, Kinniburgh RD, Nebbe B, Prasad NG, Glover KE. Tomographic assessment of temporomandibular joint osseous articular surface contour and spatial relationships associated with disc displacement and disc length. Am J Orthod Dentofacial Orthop. 2002 Feb;121(2):152-61. Pubmed PMID: 11840129.
[45]. Gateno J, Anderson PB, Xia JJ, Horng JC, Teichgraeber JF, Liebschner MA. A comparative assessment of mandibular condylar position in patients with anterior disc displacement of the temporomandibular joint. J Oral Maxillofac Surg. 2004 Jan;62(1):39-43. Pubmed PMID: 14699547.
[46]. Vasconcelos Filho JO, Menezes AV, Freitas DQ, Manzi FR, Bóscolo FN, de Almeida SM. Condylar and disk position and signs and symptoms of temporomandibular disorders in stress-free subjects. J Am Dent Assoc. 2007 Sep;138(9):1251-5; quiz 1268. Pubmed PMID: 17785392.
[47]. Zhang S, Huang D, Liu X, Yang C, Undt G, Haddad SM, et al. Arthroscopic treatment for intra-articular adhesions of the temporomandibular joint. J Oral Maxillofac Surg. 2011 Aug;69(8):2120-7. Pubmed PMID: 21470745.
[48]. Cho BH, Jung YH. Osteoarthritic changes and condylar positioning of the temporomandibular joint in Korean children and adolescents. Imaging Sci Dent. 2012 Sep;42(3):169-74. Pubmed PMID: 23071967.