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Condylar pathway changes following different treatment modalities

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SUMMARY The purpose of this investigation was to evaluate the effect of extraction and non-extraction approaches on the condylar pathways in subjects treated with fixed orthodontic appliances. The study was carried out on 70 patients (47 female, 23 male) who had undergone orthodontic treatment with fixed appliances. The mean age for the total group was 16.3 years (16.5 years for the females and 16 years for the males). Forty-seven patients were treated non-extraction and 23 with extractions. None of the patients had any temporomandibular joint (TMJ) problems before orthodontic treatment and all were treated with standard edgewise mechanics. The condylar pathway recordings were taken before and after treatment with an axiograph. The maximum opening capacity was measured and the right and left condylar pathways of each patient were recorded in protrusion and during opening movements.

During treatment the left opening angle (LOA) only decreased significantly in the upper premolar extraction group. The left opening distance (LOD) decreased in all groups during treatment but was only statistically significant in the non-extraction and upper and lower extraction groups. In the small overjet group (OJ ≤ 4 mm), the LOA, right opening distance (ROD) and LOD decreased significantly while there was no significant change in axiographic parameters in the large overjet group (OJ > 4 mm). In the latter group, overjet and overbite decreased while mouth opening (3 mm $P < 0.05$) significantly increased. These results indicate that there is no difference between the effect of different treatment protocols on the condylar pathways.

Introduction

Occlusion has been considered as an aetiological factor in the development of temporomandibular joint disorders (TMD) and orthodontic treatment procedures involving extractions have been proposed as the aetiology for the reported symptoms. However, most of the reports are either personal opinions or case studies (Tulley, 1959; Perry, 1973; Bowbeer, 1987; Reynders, 1990).

Some authors regard premolar extractions as a cause of TMD, while others consider that such extractions have minor importance for the health of the temporomandibular joint (TMJ) (Perry, 1969; Roth, 1973; Richards and Brown, 1981; Slavicek, 1981; Rieder and Martinoff, 1983; Weinberg, 1983; Droukas *et al.*, 1984; Budtz-Jörgensen *et al.*, 1985; Meng *et al.*, 1987). Kremenak *et al.* (1992a) investigated the effect of orthodontic treatment as an aetiological factor for TMD and concluded that it was not important. In a later study (Kremenak *et al.*, 1992b), they investigated premolar extractions as a risk factor for TMD. Tests for the significance of differences between mean Helkimo scores were compared between the non-extraction and extraction groups, pre- and post-treatment. They reported no significant intergroup differences between mean pre- or post-treatment scores, and small but statistically significant differences (in the direction of improvement) between mean pre- and post-treatment scores for both the non-extraction and four premolar extraction groups. Årtun *et al.* (1992) examined the hypothesis of locking the mandible in a posterior position by retraction of the upper anterior teeth. The condylar positions were determined in 29 female patients treated for Class II division 1 malocclusions with extraction of upper first premolars and 34 female patients who had undergone treatment for Class I malocclusions without extractions. They found no intergroup differences.

The relationship between extractions and TMD has been documented in several studies using questionnaires, indices and several imaging techniques (Clayton, 1985; Meng *et al.*, 1987; Gianelly *et al.*, 1991). Other authors have reported a high correlation between TMD and mandibular movements recorded by several jaw tracking devices (Van Willigen, 1979; Mongini and Capurso, 1982; Clayton, 1985; Dibbets and van der Weele, 1991). The axiograph, first introduced by Slavicek (1981), is one of the most popular. There are a number of studies using the axiograph to evaluate TMJs, but disagreement exists concerning its diagnostic value (Parlett *et al.*, 1993; Theusner *et al.*, 1993; Piehslinger *et al.*, 1994b; Rammelsberg *et al.*, 1996; Helm and Stepke, 1997). Utz and Duvenbeck (1989) reported that axiograph recordings had an error of 0.3 mm, but that the reliability of the device decreases during the recording of asymmetric jaw movements.

As the data from long-term investigations have failed to establish a causal relationship between orthodontic premolar extractions and TMD (Sadowsky and BeGole, 1980; Janson and Hasund, 1981; Larsson and Rönnerman, 1981; Madone and Ingervall, 1984; Wisth, 1984; Dibbets and van der Weele, 1987), the aim of this investigation was to study the effects of extraction and non-extraction approaches on the condylar pathways of patients treated with fixed orthodontic appliances using axiography.

Subjects and methods

The subjects were 70 orthodontic patients (47 females, 23 males) successfully treated with fixed appliances. The mean age for the total group was 16.3 years (16.5 years for the females and 16 years for the males). Forty-seven patients were treated non-extraction and 23 with extractions. The non-extraction group consisted of 16 Class I, 22 Class II, and nine Class III subjects, while the extraction group comprised eight Class I, 12 Class II, and three Class III patients. In the extraction group, 10 had their upper premolars extracted and comprised the 'U4' group, and 13 who had their upper and lower premolars extracted formed the 'UL4' group. In order to determine the effect of overjet reduction on the condylar pathways, two more groups were also formed from these 70 patients. This grouping was made according to the pre-treatment overjet values, ignoring whether or not extractions were carried out. One group included 52 subjects with overjet values equal to or less than 4 mm (OJ ≤ 4 mm) and the other 19 patients had overjet values more than 4 mm (OJ > 4 mm).

None of the patients had either previous orthodontic treatment or any TMJ problems and all were treated with standard edgewise mechanics.

The pre- and post-treatment axiographic recordings were obtained before treatment and immediately after debonding. During the recording procedure, overjet, overbite and mouth opening were measured for each patient. The right and left condylar pathways were then recorded in protrusion and retrusion and opening and closing mandibular movements using the axiograph (AXO 200, SAM Company, München, Germany) by the same operator.

Axiographic recording procedure

Clutch fixation. The clutch was filled with impression plaster and seated all the way to the occlusal/incisal surfaces and firmly pressed over the lower teeth until the occlusal surfaces contacted the inner surface of the clutch tray (Figure 1a).

Analyser bow preparation and placement. The side arms of the bow were adjusted over the ears and the analyser was fixed by placing the straps on top of the head and around the neck (Figure 1b). The first reference point was fixed at the level of the infra-orbital margin (Figure 1c, O = orbital point).

Placement of recording arm bow. Before attaching the recording arm bow to the clutch, the vertical screws were adjusted so that the arms were parallel to the cradles and the horizontal adjustment was calibrated to zero. While the patient pressed on the recording arms, the posterior edge of the recording arms were aligned to the posterior border of the recording plates at the level of the tragus. The stylus pin was inserted into the collar with the sharp end towards the patient.

Hinge axis location. One hand of the operator was cupped under the patient's chin and the other placed on top of the patient's head. The mandible was then moved up and down in the terminal hinge position. The recording arms were adjusted until the points of the stylus did not arc but remained stationary on the graph paper. The axis point was marked with articulating paper, using the blunt-ended stylus (Figure 1d).

Recording of movements. The non-recording stylus was replaced with a recording stylus which had a sharp black lead extending about 2 mm. To record the opening movement the patient was asked to open towards maximum and this movement was repeated three times. Following this the protrusive movement was recorded in the same manner starting from the hinge axis point (Figure 2a).

Reference line. A reference line was drawn between the orbital reference and the hinge axis points by clipping the axis orbital plane marker on to the ball of the first (orbital) reference point and drawing a line along the axis orbital plane marker (Figure 2b).

The overbite was measured clinically by drawing the overlap of the upper incisor on the labial surface of the lower incisor. The maximum mouth opening between the incisor edges was then measured using a vernier gauge. To calculate mouth opening, the overbite value was added to the maximum opening value for each patient (Figures 3 and 4).

The following measurements were made on the tracings (Figure 5):

1. angular (degree): the angle between the reference line and the line tangent to the initial tracing curve (a);
2. linear (mm): the distance between the initial point and the projection of the finishing point of the tracing on the reference line (b).

Homogeneity of the data was tested by Levene's homogeneity test and the intra- and inter-group differences were evaluated by two-sample *t*-test and ANOVA. In order to determine the method error of the

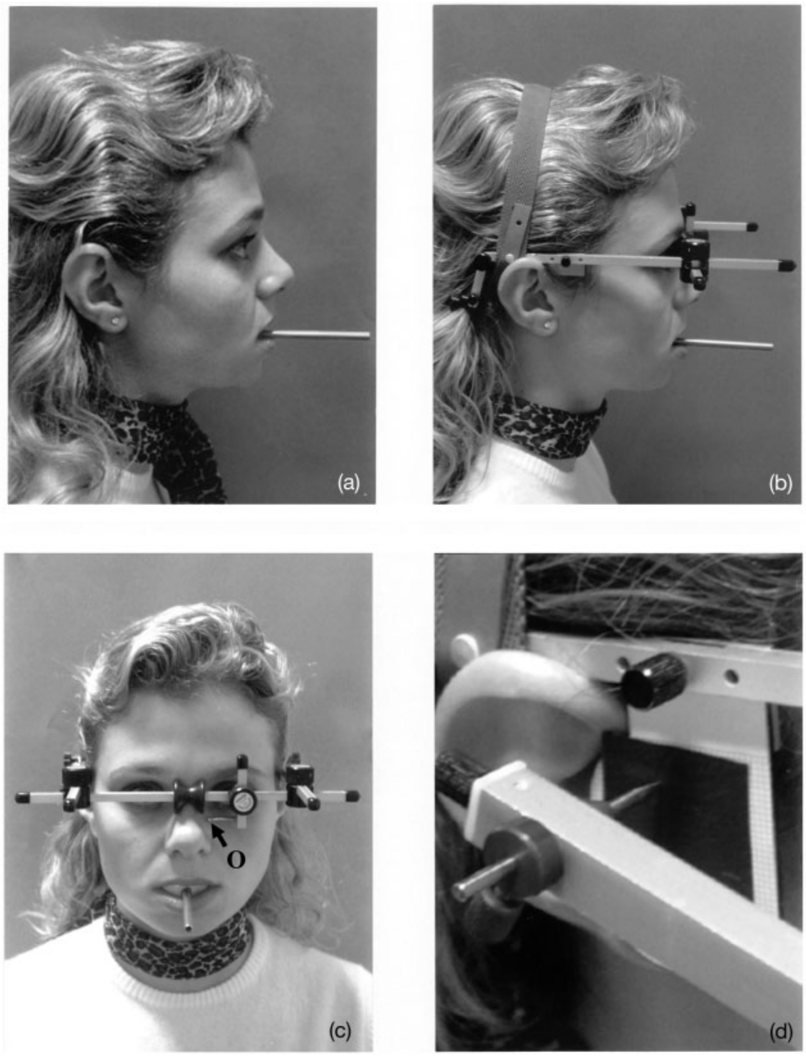

Figure 1 (a) Fixation of the clutch, (b) placement of the analyser bow, (c) orbital reference point location, (d) hinge axis location.

axiographic recording procedure, 10 randomly selected subjects were recalled, re-recorded and re-evaluated by the same operator. The difference between the two measurements was evaluated by using Dahlberg's formula. The method error was no higher than 7.49 degrees for the angular measurements and 0.78 mm for the linear measurement.

Results

Table 1 shows the values before and after orthodontic treatment and Table 2 the differences occurring during treatment in all groups. Following orthodontic treatment, mouth opening capacity increased in all groups, but was only significant in the non-extraction (1.17 mm, $P < 0.05$) and UL4 (1.69 mm, $P < 0.05$) groups. Overbite decreased in all groups but was statistically significant in the non-extraction (–1.02 mm, $P < 0.05$) and UL4 (–1.46 mm, $P < 0.005$) groups (Table 2). Overjet also decreased in all groups but was only statistically significant in the U4 (–2 mm, $P < 0.05$) and UL4 (–1.38 mm, $P < 0.05$) groups. During treatment the left opening angle (LOA) only significantly decreased (–1.45 degrees, $P < 0.05$) in the U4 group. The left opening distance (LOD) decreased in all groups during treatment but was only statistically significant in the non-extraction (–0.59 mm, $P < 0.05$) and UL4 (–0.61 mm, $P < 0.05$) groups. Other axiographic measurements did not show any significant differences during treatment. A comparison of the non-extraction group with the U4 and UL4 groups and a comparison of the two extraction groups did not show any significant differences (Table 2).

During treatment, in the OJ ≤ 4 mm group the LOA (–1.03 mm, $P < 0.05$), right opening distance (ROD; –0.19 mm, $P < 0.05$) and LOD (–0.48 mm, $P < 0.05$) decreased significantly, while there was no significant

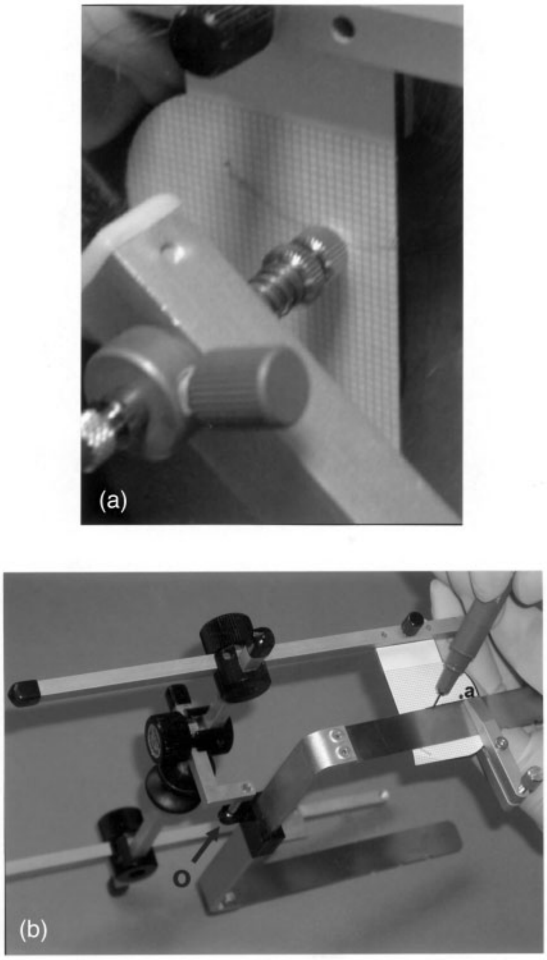

Figure 2 (a) Recording of opening movement by axiograph, (b) reference line determination.

Figure 3 Marking the overlap of the upper incisor on the labial surface of the lower incisor and measurement of incisor overlap using a vernier gauge.

Figure 4 Measuring maximum opening using a vernier gauge.

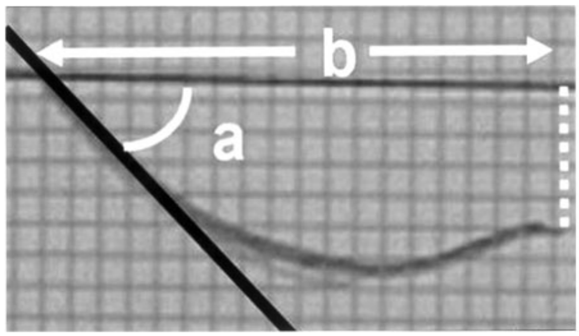

Figure 5 Measurements made on tracings.

change in axiographic parameters in the OJ > 4 mm group. In the latter group, overjet (–4.26 mm, $P < 0.05$) and overbite (–3 mm, $P < 0.05$) decreased while mouth opening (3 mm, $P < 0.05$) significantly increased.

Comparison of the two overjet groups (Table 3) revealed significant differences in mouth opening, overbite and overjet. Opening capacity increased significantly (3 mm, $P < 0.05$) in the OJ > 4 mm group, while overbite and overjet decreased significantly (–3 mm, $P < 0.05$; –4.26 mm, $P < 0.05$, respectively) compared with the OJ ≤ 4 mm group (–0.46 mm, NS; 0.11 mm, NS).

Discussion

In recent years the relationship between orthodontic treatment and TMD symptoms has been a major area of research, but high-quality data from systematic, prospective and longitudinal studies are still needed. Many investigations have used information from questionnaires, indices, and several imaging techniques.

Table 1 Mean values of non-extraction, upper premolar extraction and upper and lower premolar extraction groups before and after treatment.

	Non-extraction (n = 47)		Upper premolar extraction (n = 10)		Upper and lower premolar extraction (n = 13)	
	Mean	SD	Mean	SD	Mean	SD
Maximum opening (mm)						
Before	53.25	6.98	51.36	7.00	52.69	4.66
After	53.59	6.98	50.90	7.09	52.53	5.10
Overbite (mm)						
Before	3.23	2.63	3.09	3.23	3.61	1.50
After	2.21	0.75	1.81	0.40	2.15	0.89
Overjet (mm)						
Before	2.83	2.86	3.90	2.73	3.46	1.39
After	2.08	0.45	1.90	0.30	2.07	0.64
Right opening angle (°)						
Before	46.36	11.04	40.90	10.35	43.46	8.05
After	46.63	11.51	41.81	9.13	42.53	7.92
Left opening angle (°)						
Before	47.42	9.69	45.54	10.39	44.38	9.83
After	46.74	10.13	44.09	9.54	44.69	10.23
Right protrusive angle (°)						
Before	46.89	10.09	45.18	8.41	43.15	5.88
After	46.89	11.06	44.45	7.09	42.53	6.77
Left protrusive angle (°)						
Before	47.27	9.69	45.45	8.10	42.92	6.81
After	47.46	10.91	45.27	7.81	42.69	6.34
Right opening distance (mm)						
Before	10.63	4.45	10.81	5.07	9.92	2.66
After	10.14	3.36	10.63	4.69	9.69	2.65
Left opening distance (mm)						
Before	10.83	4.58	9.27	3.34	11.15	2.47
After	10.23	3.84	9.09	3.27	10.53	2.29
Right protrusive distance (mm)						
Before	8.19	1.59	8.90	2.25	7.84	1.72
After	8.12	1.46	9.00	2.40	7.76	1.53
Left protrusive distance (mm)						
Before	8.46	2.43	9.18	2.18	8.38	2.46
After	8.46	2.04	9.36	1.91	8.38	2.06

SD, standard deviation.

Table 2 Changes occurring during treatment and a comparison of all extraction groups.

	Non-extraction (n = 47)		Upper premolar extraction (n = 10)		Upper and lower premolar extraction (n = 13)		ANOVA	
	Diff. mean	SD	Diff. mean	SD	Diff. mean	SD	f	P
Maximum opening (mm)	1.17*	2.28	1.00	3.37	1.69*	1.49	0.83	0.43
Overbite (mm)	–1.02*	2.29	–1.27	3.22	–1.46*	1.50	0.22	0.79
Overjet (mm)	–0.74	2.80	–2.00*	2.64	–1.38*	1.44	0.37	0.68
Right opening angle (°)	0.27	4.09	0.90	2.58	–0.92	2.32	0.42	0.65
Left opening angle (°)	–0.68	3.88	–1.45*	2.38	0.30	2.35	0.79	0.45
Right protrusive angle (°)	0.00	3.24	–0.72	3.10	–0.61	2.32	0.40	0.66
Left protrusive angle (°)	0.19	3.57	–0.18	2.60	–0.23	2.04	0.12	0.88
Right opening distance (mm)	–0.48	1.96	–0.18	0.87	–0.23	0.43	0.27	0.75
Left opening distance (mm)	–0.59*	1.66	–0.18	0.75	–0.61*	0.50	0.19	0.81
Right protrusive distance (mm)	0.06	0.56	0.09	0.30	0.07	0.49	1.17	0.31
Left protrusive distance (mm)	0.00	0.75	0.18	0.75	0.00	0.70	0.31	0.73

*P < 0.05.
SD, standard deviation.
Diff. mean, difference of means.

Table 3 Mean values and a comparison of the two overjet groups.

	Overjet ≤ 4 (n = 51)				Overjet > 4 (n = 19)				P
	Before mean	After mean	Diff. mean	SD	Before mean	After mean	Diff. mean	SD	
Maximum opening (mm)	50.51	51.11	0.59	2.41	46.84	49.84	3.00*	0.57	*
Overbite (mm)	2.50	2.03	–0.46	2.34	5.42	2.42	–3.00*	0.57	*
Overjet (mm)	1.92	2.03	0.11	1.56	6.36	2.10	–4.26*	2.10	*
Right opening angle (°)	46.23	46.05	–0.17	2.51	41.57	42.63	1.05	5.67	
Left opening angle (°)	47.73	46.69	–1.03*	2.84	43.42	43.94	0.52	4.64	
Right protrusive angle (°)	46.11	46.11	–0.07	2.65	45.26	44.63	–0.63	4.00	
Left protrusive angle (°)	46.63	46.63	0.00	2.52	45.00	45.21	0.21	4.62	
Right opening distance (mm)	10.28	10.09	–0.19*	0.56	11.21	10.26	–0.94	3.03	
Left opening distance (mm)	10.76	10.28	–0.48*	0.57	10.31	9.63	–0.68	2.58	
Right protrusive distance (mm)	7.98	7.96	–0.02	0.50	8.94	8.84	–0.10	0.56	
Left protrusive distance (mm)	8.36	8.46	0.09	0.72	9.10	8.94	–0.16	0.76	

*P < 0.05.
SD, standard deviation.
Diff. mean, difference of means.

However, it has been suggested that discrimination between healthy and diseased TMJs can be made by measuring movements (Gsellmann *et al.*, 1998). In this study the aim was to evaluate the effect of different treatment procedures on the condylar pathways using axiographic recordings.

The results show that mouth opening capacity increased during treatment in all groups, but was only significant in the non-extraction and all four extraction groups (1.17 and 1.69 mm, respectively). The LOD decreased in all groups but was only significant in the non-extraction and UL4 groups. However, the values (–0.59 and –0.61 mm, respectively) were very small.

A comparison of the small and large overjet groups showed that mouth opening capacity increased significantly more (3 mm) in the large overjet group during treatment while there was no change in condylar pathway movement. In the small overjet group, ROD and LOD decreased significantly (–0.19 and –0.48 mm, respectively) during treatment. The opening value for the small overjet group was 50.51 mm before and 51.11 mm after treatment. These values are comparable with those of Theusner *et al.* (1993) who reported an opening distance of 50.2 ± 3.9 mm for asymptomatic individuals, indicating that this is not a pathological situation.

Do these slight changes suggest any TMD problem? As no comparable study has been undertaken with jaw tracking devices on similar groups, the findings cannot be compared. Therefore, the pre- and post-treatment data were compared with studies determining normal values of the condylar pathways.

This analysis showed that condylar pathway measurements (before and after treatment) were within the normal range according to the values of Piehslinger *et al.* (1994a) who investigated mandibular movement in males and females in three dimensions using computerized axiography.

Comparison of the non-extraction and extraction groups and the U4 and UL4 groups did not show any significant difference, indicating that there was no particular effect of different treatment procedures (with or without extractions) on the condylar pathways.

There are many investigations which support these findings. Kremenak *et al.* (1992a) studied the effect of premolar extractions on TMD and found no difference between patients treated with or without extractions. They also reported an improvement compared with the pre-treatment situation. Dibbets and van der Weele (1991) also found that craniomandibular dysfunction problems, for example pain, limitation of mouth opening, crepitation, and condylar deformation, did not appear to be related to non-extraction treatment or any type of premolar extraction. Henrikson and Nilner (2000) compared 60 normal occlusion cases with 65 Class II treated and 58 Class I non-treated after 2 years of follow-up and reported that orthodontic treatment does not increase the risk of TMD. They also found that pre-treatment TMD signs of muscular origin seemed to benefit functionally from orthodontic treatment.

Crawford (1999) compared the condylar axis positions of restored and untreated patients and found that the axis did not move forward or backward but downward (predominantly downward and backward) in the untreated group. At the 10 year follow-up, the condylar axis position was stable in the restored group, which he considered was similar to orthodontically treated cases.

First premolar extractions have been suggested as an aetiological factor for TMD (Tulley, 1959; Wilson, 1971; Levy, 1979; Bowbeer, 1987; Witzig and Spahl, 1987; Wyatt, 1987). Some authors believe that extraction causes anterior movement of posterior teeth which creates a decrease in vertical occlusal dimension, as a result of which the mandible overcloses, and the mastication muscles become foreshortened, which may lead to the development of TMD. This theory was analysed and rejected by Staggers (1994) who reported that the mean values of the vertical dimension after treatment were increased in the extraction group and that the non-extraction group also showed similar vertical changes.

It has also been proposed that orthodontic extractions lead to over-retraction of the upper anterior teeth which causes displacement of the mandible during closing, such that the condyles move distally (Levy, 1979; Farrar and McCarty, 1983; Witzig and Spahl, 1987). Posterior localization of the condyles has long been suggested as a cause of TMD. However, Gianelly *et al.* (1988), in an investigation of the condylar position of patients treated orthodontically with extraction of first premolars and compared with a non-extraction control, found no differences between the groups and also no relationship between deep bite and condylar position. In another study, Gianelly *et al.* (1991) compared the condylar position of patients treated orthodontically with extraction of upper premolars only with untreated patients, and again found no difference between the groups. Kundinger *et al.* (1991) also supported this conclusion. A study by Luecke and Johnston (1992) showed, contrary to current beliefs, an actual forward displacement of the mandible during upper first premolar extraction treatment. They also found that the condylar position did not correlate with the amount of incisor retraction. None of these studies supports the idea that incisor retraction causes posterior displacement of the condyles.

The findings of current research investigating the relationship between orthodontic treatment and TMD have been summarized by McNamara (1997) as follows: (1) signs and symptoms of TMD may occur in healthy persons; (2) signs and symptoms of TMD increase with age (during adolescence, until menopause), thus problems occurring during treatment may not be related to that treatment; (3) in general, orthodontic treatment performed during adolescence does not increase or decrease the chances of developing TMD in later life; (4) the extraction of teeth as part of an orthodontic treatment plan does not increase the risk of TMD; (5) there is no increased risk of TMD associated with any particular type of occlusion or mechanics; (6) stable occlusion is a reasonable orthodontic treatment goal, but not achieving a specific gnathological ideal occlusion does not result in signs and symptoms of TMD; (7) there is little evidence that orthodontic treatment prevents TMD, although the role of unilateral posterior cross-bite correction in children may warrant further investigation.

Conclusion

The results of the present research do not suggest any particular effect of different treatment procedures (with or without extractions) on the condylar pathways.

Further studies are required using larger samples to compare post-treatment condylar pathways with an age-matched control sample to distinguish changes occurring due to continuing mandibular growth.

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