Radiographic structural findings in the mandibular condyles of young individuals receiving orthodontic treatment

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Radiographic findings in mandibular condyles were studied from the pre- and post-treatment panoramic radiographs of 625 orthodontic patients. The subjects' mean age was 11 years at the start and 14 years at the end of active orthodontic treatment. Radiographic condylar findings were seen in 14 (2%) subjects before treatment and in 54 subjects (9%) after treatment ($p < 0.001$). In age-related controls ($n = 783$) condylar findings were seen in 3% ($p < 0.001$). The condylar finding was 'flattening only' in half of the patients and in one-third of the controls with condylar findings. Activator treatment was associated with condylar findings ($p < 0.05$). Condylar findings increased with age in the orthodontically treated subjects ($p < 0.05$) but not in the unselected population controls. This may mean that condyles become more sensitive with age in children. Increase with age may be partly due to the radiographic interpretation, since minor condylar findings are difficult to observe in young children, and partly due to differences in treatment modalities and the duration of treatment. □ *Orthodontics; radiography, panoramic; temporomandibular joint*

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The relationship between orthodontic treatment and craniomandibular disorder (CMD) or temporomandibular joint dysfunction (TMD) has been widely discussed in the literature during the last few years (1–15). In spite of the large number of studies, agreement has not yet been reached.

The number of published radiographic examinations is small. In a longitudinal study Dibbets (16) and Dibbets & van der Weele (1, 2) used radiographs in accordance with the Parma method, to evaluate the state of mandibular condyles. They concluded that although there is a slight increase in the frequency of condylar findings during the first 2 years of orthodontic treatment (Begg technique or activator treatment), this increase is associated with increasing age, not with orthodontic treatment. In the study by Hansen et al. (5) lateral tomography showed structural bony changes in the condyles of 1 of 19 patients after Herbst appliance treatment. Årtun et al. (17) recorded no degenerative findings in the condyles in their group of 29 female subjects with Angle class II/1, who were treated with extractions of two maxillary premolars (and headgear and class-II elastics). In a recent panoramic radiographic study among young Finnish adults (18) there were significantly more radiologic findings in the condyles of orthodontically treated patients than in untreated controls.

The aim of the present study was to compare radiographic structural findings in the mandibular condyles of orthodontically treated young patients with findings in normal populations, including children with only minor or no orthodontic treatment in three age groups. The other aim was to ascertain whether different treatment methods were associated with radiographic findings in the mandibular condyles.

Materials and methods

The original material for the present study consisted of the patient records and pre- and post-treatment panoramic radiographs (PR) of 1090 orthodontic patients at the Department of Pedodontics and Orthodontics, Institute of Dentistry, University of Helsinki. The treatment of most of the patients had started between February 1973 and September 1983. The subjects selected were those whose age at the start of the treatment was between 8 and 15.9 years. Altogether 480 patients were excluded for the following reasons: interrupted treatment ($n = 98$), condyles not visible on radiograph ($n = 18$), one of the two radiographs missing ($n = 167$), patient too young ($n = 89$), and other reasons (patient too old, trauma, or inflammatory disease in mandibular condyles) ($n = 108$). To increase the number of patients treated with a chincap, 15 subjects were included from outside the original sample. The final sample thus consisted of 625 orthodontically treated patients (Table 1). For more details see Peltola et al. (19).

The mean age of the patients was 11.0 years (SD, 1.7) at the start of the active treatment and 14.5 years (SD, 1.7) at the end of the treatment. The mean duration of the active treatment was 3.0 years (SD, 1.5). Post-

Table 1. Age distribution of orthodontically treated patients and radiographic controls (Finns + Estonians = all controls)

Age (years)	Male	Female	Total
8–10	3 (54)	1 (62)	4 (116)
11	4 (18)	6 (44)	10 (62)
12	21 (43)	42 (12)	63 (55)
13	42 (18)	61 (21)	103 (39)
14	71 (38 + 40 = 78)	79 (5 + 59 = 64)	150 (43 + 99 = 142)
15	75 (9 + 28 = 37)	69 (4 + 67 = 71)	144 (13 + 95 = 108)
16	29 (1 + 24 = 25)	41 (11 + 67 = 78)	70 (12 + 91 = 103)
17	16 (15 + 32 = 47)	35 (32 + 65 = 97)	51 (47 + 97 = 144)
18–19	8 (7)	22 (7)	30 (14)
Total	269 (203 + 124 = 327)	356 (198 + 258 = 456)	625 (401 + 382 = 783)
Mean age	14.4 (13.0; 15.4; 14.1)	14.5 (13.1; 15.6; 14.7)	14.5 (13.0; 15.5; 14.6)
SD	1.5 (2.3; 1.2; 2.0)	1.9 (2.8; 1.1; 2.0)	1.7 (2.6; 1.1; 2.0)

treatment radiographs were taken on an average 0.5 years (SD, 0.98) after the end of the active treatment. Active removable plates and fixed appliances were the most usual appliances used (Table 3). Most patients (82.2%) had more than one type of appliance during their active treatment. The number of patients treated with extractions is given in Table 3.

The children were divided into three groups on the basis of their age at the time of the post-treatment radiographs: less than 12, 12–15.9, and 16 years and more, to study the associations among orthodontic treatment, patients' age, and condylar findings. The age limits were selected on the basis of earlier TMD studies (4, 20–22).

The original roentgenologic control group consisted of 401 PRs from 1964 and 1965 taken of schoolchildren in the city of Helsinki (23). To increase the number of 14- to 17-year-old controls, another control group of PRs of 382 Estonian schoolchildren from Tartu and Tallinn was included (J. Peltola et al. Unpublished observations). The children were from different schools for Estonian-speaking children, and their radiographs were taken in 1993. The age distributions of the patients and the controls are given in Table 1.

The radiographs of orthodontic patients and Finnish controls were taken at the Department of Dental Radiology, Institute of Dentistry, University of Helsinki. The controls were radiographed with an Orthopantomograph OP 2 (with Siemens Biangulix Rapid roentgen tube, focus 0.3 × 0.3 mm) and the patients with an Orthopantomograph OP 2, OP 3, OP 10, or Cranex DC I. In Estonia the PRs were taken in 1993, using a Cranex DC I in Tartu and a PM 2002 CC in Tallinn. All radiographs in which condyles were not clearly visible were excluded. All radiographs of the patients and controls were evaluated by one experienced examiner (J. S. Peltola). Radiographs with positive condylar findings and unclear cases were re-evaluated by another experienced examiner (M. Könönen). Only those findings on which both examiners agreed were recorded.

Seven different types of radiologic findings in the condyles were recorded: 1) flattening of the articular surface (a flat bony contour deviating from the convex form, in grade 1, less than or equal to one-third of the articular surface; in grade 2 more than one-third of the articular surface is affected); 2) subcortical sclerosis (local area with increased density of the cortical bony joint surface extending into the subcortical area); 3) osteophyte (a marginal bony outgrowth); 4) microcyst (a well-defined, local area of bone rarefaction underneath an intact cortical outlining of the joint surface); 5) marginal erosion (a local area with decreased density of cortical joint surface and adjacent subcortical bone); 6) periarticular ossicle (calcification in the joint space); and 7) other findings, including deformities (gross deviation in size and form). Types one to five were recorded on the basis of criteria published by Rohlin et al. (24). The radiographic findings were graded as follows: 0 = none; 1 = mild; and 2 = clear/pronounced (25) (Fig. 1).

To estimate the inter-examiner variation and intra-examiner reproducibility, agreement percentages and kappa indices (26) were calculated. For inter-examiner variation, two of the authors (J. S. Peltola and M. Könönen) evaluated 100 radiographs (200 condyles) as either finding or no finding. For intra-examiner (J. S. Peltola) reproducibility, 100 radiographs (200 condyles) were examined 3–5 months after their first evaluation. The radiographs, which were evaluated blind, consisted of 50 radiographs of orthodontic patients and 50 of controls, and they included more than the average number of radiographs with structural findings. They were all chosen by a third person. In the inter-examiner and intra-examiner variations, the agreement percentages were 94% and 92%, and the kappa indices 0.55 and 0.58, respectively.

The chi-square test and Fisher's exact test were used

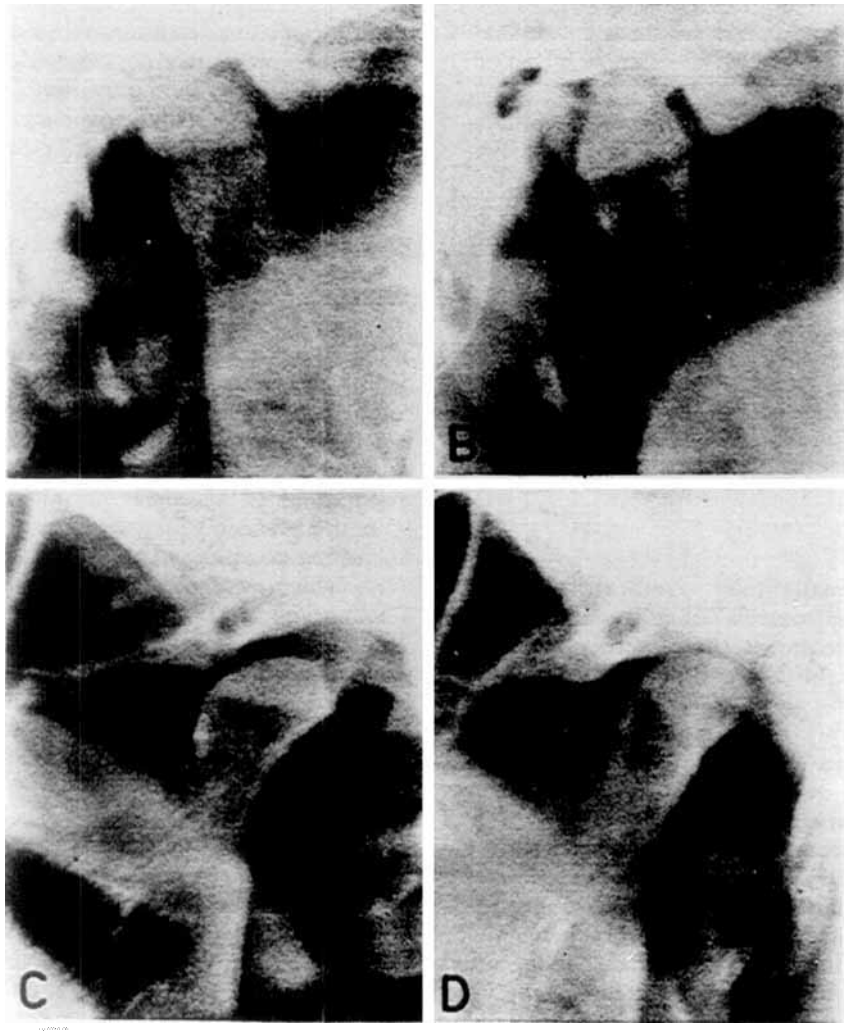

Fig. 1. A patient's normal right condyle before treatment (A) and flattening grade 1 after treatment (B). Normal left condyle before treatment (C) and flattening grade 2 and osteophyte grade 2 after treatment (D) of another patient.

to analyze the statistical significance of differences between patients with structural findings in their condyles and all patients in different treatment methods, between patients before and after orthodontic treatment and between patients and controls. The chi-square test and Fisher's exact test were also used to analyze the statistical significance of differences between age groups and between treatment durations in different age groups. Because almost all treatments included many kinds of treatment methods, those methods associated with condylar findings were studied after subjecting other accompanying treatment methods and the patients' ages to logistic regression analysis.

Results

The number of different condylar findings and their severity are given in Table 2. The condylar findings were bilateral in 13 patients and unilateral in 41 patients (23 right and 18 left condyles). One type of condylar finding was seen in 37 patients, 2 types of findings in 12 patients, 3 types in 4, and 4 types of findings in 1 patient. The most common combination was flattening of the articular surface and subcortical sclerosis.

There were no statistically significant differences in the frequency of condylar findings between males and females, either in patients or in Finnish controls. In the Estonian controls girls had more condylar findings than boys ($p < 0.05$). The slight differences between the frequency of condylar findings in 14- to 17-year-old Estonian controls (3%) and in Finnish controls of the same age (5%) and all the Finnish controls (3%) were not statistically significant. Thus the results are given for sexes and for Finnish and Estonian control groups combined.

Table 2. Number of different condylar findings on the basis of their severity in 54 patients and 26 controls: 1 = mild; 2 = clear/pronounced. Number of controls in parentheses

	Right condyle, $n = 36$ (18), severity		Left condyle, $n = 31$ (10), severity	
Radiographic finding	1	2	1	2
Flattened articular surface	22 (9)	5 (6)	8 (2)	11 (5)
Subcortical sclerosis	7 (4)	4 (6)	7 (1)	4 (2)
Osteophyte	3	1 (2)	2	2 (1)
Microcyst	2	0	0	0
Marginal erosion	1	0 (1)	1	1
Periarticular ossicle	1	0	0	0
Other	0	5	0	3 (3)
Total	36 (13)	15 (15)	18 (3)	21 (11)

There were no statistically significant differences between patients and controls before treatment. At the beginning of the treatment there were radiographic condylar findings in 14 (2%) of the children and after treatment in 54 (9%) ($p < 0.001$). Condylar findings were seen in 26 (3%) of the children in the control group. The difference between subjects and controls was significant in the age groups 12–15.9 years ($p < 0.05$) and 16 years and more ($p < 0.001$). When the age groups were combined, the difference was highly significant ($p < 0.001$). In 27 (4%) patients (50% of patients with condylar findings) and in 9 (1%) controls (35% of controls with condylar findings) the condylar finding was flattening of the articular surface only. When patients and controls with flattening only were excluded, the percentage of individuals with condylar findings was higher ($p < 0.05$) in the subjects (4%) than in the controls (2%).

Of the 14 children with condylar findings at the start of the treatment, 6 had normal condyles after treatment, 3 were unchanged, and in 5 the condylar findings had become more severe. All condyles that had become normal were grade-1 cases, and all unchanged condyles were grade-2 cases. Condylar changes had appeared during the treatment in 46 children.

The frequency of condylar findings after treatment increased in the patients ($p < 0.05$) with age (calculated between the three age groups ($p < 0.05$) and also as continuous variables ($p < 0.01$)), whereas in the controls the increase with age was non-significant. The duration of the treatment increased from younger to older age groups ($p < 0.001$) (Table 3).

Of the different orthodontic treatments, activator treatment was associated with radiographic findings in the mandibular condyles in the age group 12–15.9 years ($p < 0.05$) and in all patients ($p < 0.05$) when the patients' age was standardized. Logistic regression analysis also showed that activator treatment was associated with condylar findings. In other treatment modalities no association was found between the use of appliances in the maxilla, mandible, or both jaws and condylar findings. The duration of the treatment was associated with a greater frequency of condylar findings in patients 16 years or more ($p < 0.05$).

Discussion

The quality of the radiographs taken of the controls in 1964 and 1965 was as good as that of the radiographs of the patients and Estonian controls, because they had been taken using equipment with a small focus and rotating anode. The use of different X-ray machines has no substantial effect on the results (27–33). Radiographs exposed in any of the units are basically reliable representations of the object morphology (34).

In the present study the inter- and intra-examiner variations as expressed by kappa indices were moderate (35), which is in line with earlier studies (36, 37). Cholitgul et al. (37) reported that condylar sclerosis is very often a false-positive finding in sagittal tomography compared with histologic findings, which should be kept in mind when the results of the present study are interpreted.

We found no epidemiologic radiographic study of the frequency of condylar findings in a normal child population. Getting suitable controls was one problem in the study design. In every Finnish district orthodontic treatment has been provided for most of the children in need. So it was impossible to obtain contemporary controls, in which children with malocclusions had not already been sorted out. Our Finnish controls are from the 1960s, when orthodontic treatment was still uncommon in Finland, so the effect of orthodontic treatment on condylar findings, in this population, should be minimal. The Finnish and Estonian controls consisted of normal whole classes of schoolchildren and can thus be considered to represent a normal population. Since Estonians are close ethnic relatives of the Finns, the use of a combined control material was considered justified, particularly as the frequencies of condylar findings did not differ statistically. Orthodontic treatment in Estonia is still rather rare.

Flattening of the articular surface only was the finding seen in half of the 54 patients and in one-third of the 26 controls with condylar findings. When this kind of finding appears alone, it is probably either remodeling of the bony surface or else due to growth (38). Åkerman et al. (39) stated that flattening of the articular surface and minor osteophytes and sclerosis in elderly people are signs of remodeling, but whether osteophytes and combined findings are normal in young adolescents is open to question. Nevertheless, the percentage of condylar findings in orthodontically treated patients remained significantly higher even when the patients and controls with the finding 'flattening only' were excluded. The clinical meaning of this finding might

Table 3. Number of patients in three age groups with different treatment methods and number and percentage of condylar findings in an individual treatment group and statistical differences between patients and controls

	< 12 years				12–15.9 years				> 16 years			
		Duration of treatment	Children with findings			Duration of treatment	Children with findings			Duration of treatment	Children with findings	
	n	$\bar{x}$ (SD)	*n*	%	*n*	$\bar{x}$ (SD)	*n*	%	*n*	$\bar{x}$ (SD)	*n*	%
Appliance												
Fixed	1	1.2	0	0	260	1.7 (0.9)	18	7	98	2.2 (1.2)	13	13
Removable	8	1.3 (0.7)	0	0	281	1.5 (1.2)	20	7	93	2.2 (1.4)	13	14
Activator	1	2.5	0	0	48	1.9 (1.0)	7	15	20	2.4 (1.2)	4	20
Head gear	5	1.0 (1.0)	0	0	257	1.8 (1.0)	16	6	76	2.1 (1.3)	12	16
Chincap	3	2.1 (1.1)	0	0	23	3.3 (2.7)	2	9	12	3.4 (2.3)	1	8
Functional corrector	0				9	1.7 (1.3)	1	11	2	2.3 (2.2)	0	0
Extraction	3		0	0	212		12	6	94		13	14
Patients	14	1.9 (1.2)	0	0	460	2.9 (1.4)	33	7	151	3.5 (1.8)	21	14
				NS				*				***
Controls	178		3	2	344		11	3	261		12	5

* $p < 0.05$; *** $p < 0.001$; NS = not significant.

be insignificant because many studies conclude that orthodontic treatment has no connection with TMD (1–4, 10, 12, 14, 16) or even may help alleviate the symptoms of TMD (8, 11, 40, 41).

Associations between condylar findings and different treatment methods are difficult to detect by means of this kind of retrospective study model, since several appliances were often used either simultaneously or in succession during the same treatments. Although the frequency of condylar findings was highest in activator treatments, the other treatments, before or after the activator, may interfere with the results, and the association between activator treatment and condylar findings remains questionable.

The frequency of condylar findings was significantly higher in the orthodontically treated subjects than in controls, although most of the findings are probably connected with remodeling. It should also be kept in mind that craniofacial configuration and occlusion certainly differed more from ideal in orthodontic patients than in the unselected control population, although no significant differences in the frequency of condylar findings were found between patients and controls before treatment (19).

The percentage of condylar findings after treatment in the present study is much lower (9% versus 24%) than in the earlier studies of Dibbets and his co-workers (1–3, 16, 42). In the study of Dibbets & van der Weele (2) 69% of the patients belonged to Angle class II/1, and most of them were treated with an activator or the Begg technique. In the present study condylar findings were more frequent (16%) in children treated with an activator than in other treatment groups (8–9%). Children with a history of trauma were included in the Dibbets studies but excluded in the present study. The transpharyngeal radiographic method in accordance with Parma used by Dibbets may provide more information than panoramic radiography (43). These facts together may explain the greater percentage of condylar abnormalities in the studies of Dibbets and his co-workers.

The frequency of patients with condylar findings increased significantly during the orthodontic treatment in the present study, and the difference between patients and controls increased with age. Lindahl & Hollender (44) studied remodeling of the TMJ after condylar fractures and found that joints became normal more often in children 3–11 years old than in 12- to 19-year-olds at the age of fracture. Studies on experimental animals also suggest that growing cartilage is more resistant to altering functional loading patterns (38). An age-related increase in the percentages of condylar findings in orthodontic patients may mean that condyles are more sensitive in older children. The fact that the treatment period was longest in the oldest age group and that differences in treatment modalities between patients less than 12 years and older patients may also be associated with the age-related increase in condylar findings in the present study. Furthermore, the cortical outline of the condyle is not definite in children, and therefore minor condylar findings are considered to be difficult to observe radiographically in young children. The outline of the condyle of individuals more than 16 years old is easier to perceive, especially so since most individuals in this age group of the present study were females. These biologic factors in radiographic interpretation may also affect the age-related increase in condylar findings.

In conclusion, 1) radiographic condylar findings, probably clinically insignificant, were more frequent in

orthodontic patients soon after active treatment than in populations in which orthodontic treatment was rare; 2) activator treatment was the only treatment modality associated with condylar findings, although the association still remains obscure because of the many treatment modalities used in most patients; and 3) in orthodontically treated children the frequency of radiographic condylar findings increased with age, probably being partly due to the radiographic interpretation, differences in treatment modalities, and the duration of treatment.

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