Temporomandibular joint condyle changes after surgically induced non-reducing disk displacement in rabbits: a macroscopic and microscopic study

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Experimentally induced displacement of the temporomandibular joint (TMJ) disk has previously been shown to induce shortening of the mandibular ramus on the ipsilateral side. The aim of this investigation was to reveal whether this shortening develops due to primary influence on condyle growth or by secondary loss of condyle mass due to degenerative tissue breakdown. Disk displacement was created in the right TMJ in seven 3-month-old rabbits, the posterior disk attachment kept intact. Seven rabbits underwent surgical opening of the TMJ without disk intervention. Seven additional animals served as references. After a 3-month experimental period, the animals were sacrificed. Previous analysis revealed shortening of mandibular height and length caused by ipsilateral TMJ disk displacement. The condyles were examined macroscopically and by histologic sectioning or scanning electron microscopy. All condyles were covered with smooth articulating soft tissue and without visible signs of degenerative changes. Four condyles from joints with disk displacement demonstrated substantial regressive remodeling resulting in a change of condyle shape with forward/downward rotation of an enlarged articulating surface. It was concluded that TMJ disk displacement in a growing individual can induce reduction of mandibular height and length before a stage where visible osteoarthrotic changes develop. It implies a primary adverse effect on condyle growth. □ *Disk displacement; histology; rabbit; scanning electron microscopy; temporomandibular joint*

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Deviation in craniofacial growth has been reported in patients with temporomandibular disorders (TMD) (1). TMD, however, is a collective term embracing multiple conditions afflicting the temporomandibular joint (TMJ) as well as the entire masticatory system. Hence, it remained obscure whether deviant mandibular growth was associated with any specific condition, especially when the signs and symptoms of different conditions were alike. The development of new radiographic techniques during the last few decades, e.g., arthrography, computed tomography, and magnetic resonance imaging, has made it possible to separate arthrogenous from myogenous causes in TMD patients, even when the signs and symptoms of different conditions are similar. A correlation was then found between facial asymmetry and the presence of unilateral TMJ disk displacement (2). Whether the asymmetry predisposed for the development of TMJ disk displacement or the joint condition induced facial asymmetry was not delineated and thus causation remained unclear.

Experimental studies showed that altered masticatory function, following unilateral removal of occlusal contacts, influenced mandibular growth in rabbits (3), as did mandibular hypomobility in monkeys and in humans regardless of whether the impaired function was caused by intraarticular or extraarticular obstacles (4–6). Because disk displacement is a common TMJ affliction and it typically changes the function of the joint, increasing interest has recently been focused on this condition and its association with deviant mandibular growth. In order to reveal the causation, unilateral displacement of the disk was surgically created in growing rabbits by a transverse cut through the posterior disk attachment (7). The intra-individual asymmetry of mandibular height observed at the end of the experimental period was attributed to a unilateral shortening due to osteoarthrosis with partial destruction and flattening of the condyle. Surgical perforation of the disk per se (8) and the posterior disk attachment (9) have previously been shown to induce both macroscopic and microscopic osteoarthrotic changes of the condyle in rabbits (8). It therefore remained unclear if disk displacement primarily influenced mandibular growth or if the surgical procedure was responsible for the asymmetry by inducing osteoarthrotic changes of the condyle (7, 9).

The development of an experimental surgical model that displaced the disk with the posterior disk attachment intact over the condyle rendered it possible to avoid creation of osteoarthrosis by means of the surgical technique (10). To study the influence of an early stage of TMJ disk displacement on growing rabbits, we experimentally created unilateral disk displacement with the posterior disk attachment kept intact. Shortening of ramal height and mandibular length developed on the ipsilateral side as accounted for in previous studies (11, 12).

The aim of this investigation was to reveal if the shortening of the mandibular ramus developing in growing rabbits after displacement of the TMJ disk is due to a primary influence on mandibular growth or if it is due to loss of condyle mass caused by osteoarthrosis.

Material and methods

The material was composed of 21 growing New Zealand white rabbits (*Oryctolagus cuniculus*) used in previous studies (11, 12). The animals were between 90 and 91 days old at the beginning of the experiment and the experimental period lasted for 3 months. Hence, the experimental period coincided with the growth period of the rabbit (13). They were divided into 3 groups with 7 animals in each: (i) experimental group, (ii) sham group, and (iii) reference group. The animals in the experimental and sham groups were subjected to a surgical opening into their right TMJ. In the experimental animals, the TMJ disk was anteriorly displaced, and in the sham animals the joint was opened to expose the articular tissues but without any further intervention. The animals in the reference group served as controls. One animal in the sham group died of an unknown cause before the experiment was terminated.

Surgical creation of non-reducing disk displacement

The animals in the experimental and sham groups were premedicated with 2–6 ml of Atropin (atropine sulphate 0.5 mg/ml) per kilogram body weight subcutaneously administered. The purpose was to reduce secretion in the respiratory tract. General anesthesia was achieved with 0.5 ml subcutaneously administered Diazepam (diazepam 5 mg/ml) per kilogram body weight and 0.2–0.3 ml Hypnorm per kilogram body weight, intramuscularly administered.

In all animals in the experimental and sham groups, the right TMJ was approached through a skin incision posterior to the orbit. The soft tissue covering the joint was bluntly dissected until the joint capsule was revealed. To achieve sufficient field of surgical view, approximately 3 mm of the anterior part of the zygomatic arch was removed with a dental bur. The continuity of the zygomatic arch was maintained. An incision was made through the joint capsule, exposing the disk. In the sham animals, but not in the experimental animals, the joint was flushed with saline and the wound closed. No disk manipulation was performed. In the experimental animals a ligature was sutured to the anterior part of the disk. The medial, anterior, and lateral disk attachments were loosened and the disk was pulled forward. The posterior disk attachment was kept intact and covered the condyle. To maintain the anterior displacement of the disk, the ligature was fixed to the zygomatic arch by a suture through a small drilled hole. Articulatory mandibular movements were manually performed to verify the anterior disk displacement during all jaw movements and to check that the joint tissues were not too tightly sutured. The surgical area was flushed with saline and the wound closed.

The animals were given approximately 0.1 ml Temgesic (buprenorphine 0.3 mg/ml) subcutaneously per kilogram body weight postoperatively, for analgetic effect and approximately 50 ml of saline subcutaneously to prevent dehydration. After the operation, the animals had free access to their ordinary food, which was pellets and water.

The animals were sacrificed after an experimental period of approximately 90 days. The euthanasia procedure was performed with an intramuscular injection of 1.5–2 ml of Hypnorm per kilogram body weight and with saline perfusion of the vascular system of the cranial part of the body through a heart puncture until the blood was drained from the vessels.

Preparation of specimens

Each mandible was separated from the rest of the head. All soft tissues except the articulating soft tissues were removed. The specimens were fixed in sodium phosphate buffered 2.5% glutaraldehyde (14) with 0.06% sodium azide added as an antimicrobial agent.

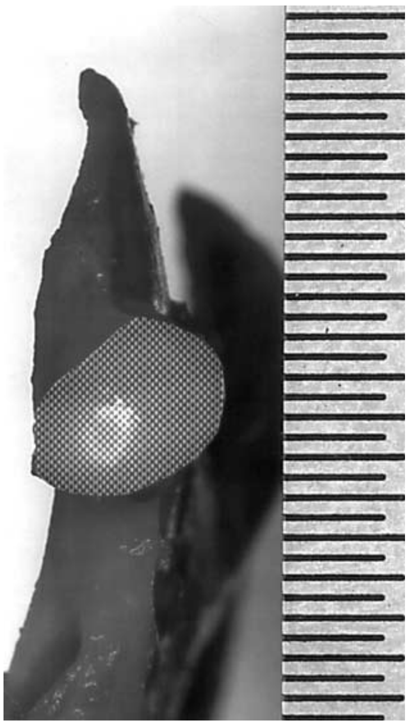

Fig. 1. The axially projected articulating surface of the condyle as defined and marked (shadowed area).

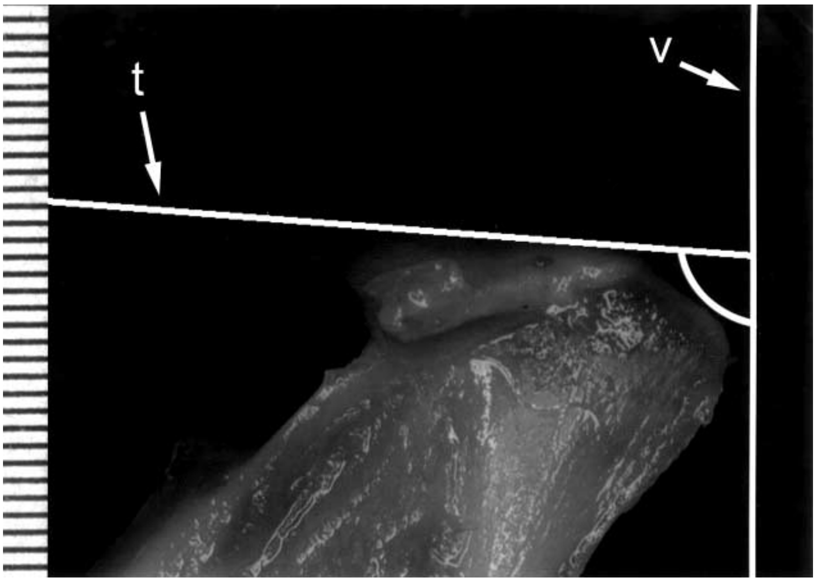

Fig. 2. Measurement of the angle between a tangent (t) to the articulating surface and a vertical line (v). The specimen is placed with the mandibular base on a horizontal surface, which is perpendicular to the vertical line marked in the photograph.

Macroscopic evaluation

All 40 condyles from the 20 animals were photographed in lateral and axial views according to a standardized protocol. The photographs were taken with a Micro-Nikkor 105 mm f/2.8D lens (Nikon, Japan) and Kodak EPP 100 positive color film (Kodak, EC), developed, digitized with an Agfa Arcus II scanner (Agfa, Germany) using 1200 dpi resolution, and computer stored. At photography, the specimen was placed with the mandibular base resting on a horizontal surface. The camera was fixed to a stand with the film plane:

(i) parallel to a tangent to the articulating surface of the condyle in order to measure the projected area of the articulating surface. A reference scale (0.5 mm) was mounted adjacent to the specimen to allow for measurements in the pictures. The borderline of each articulating surface was identified in the axial view and marked in a blinded mode (Fig. 1). The area within the contour was measured in a Leica Q500MC computer using Leica Q500MC Qwin V01.01 software (Leica, Germany)

(ii) parallel to the lateral aspect of the mandibular ramus in order to measure the angle between the articular surface and a vertical line (Fig. 2).

Microscopic evaluation

A total of 11 animals, 3 from the experimental group and 4 from each of the sham and reference groups, were randomly selected for histologic analysis. Both condyles from each animal were evaluated. The condyles were separated from the mandible with a fine-toothed saw and decalcified in 20% formic acid for 7 days. The decalcified specimens were embedded in paraffin and sagittally

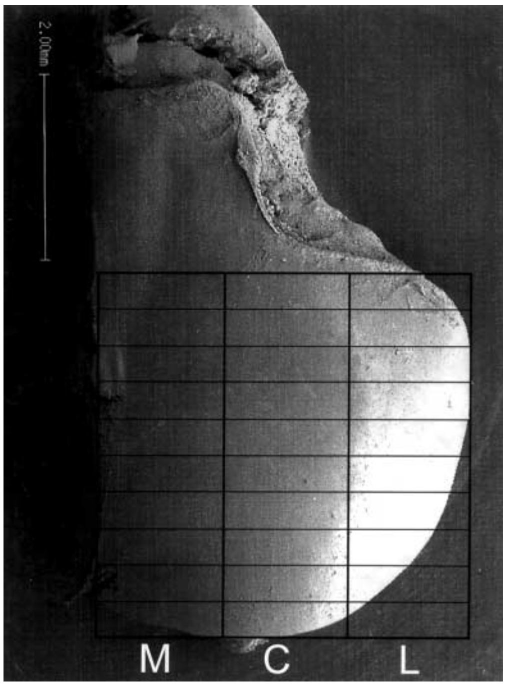

Fig. 3. A scanning electron microscopic surface survey of a condyle with a grid superimposed to illustrate the distribution of micrographs studied at higher magnification. (L = lateral zone; C = central zone; M = medial zone).

Table 1. Angle, shape, and size of the articulating surface of the condyle

	Operated/right side			Non-operated/left side	
	Angle	Condyle shape	Area ratio right:left	Angle	Condyle shape
Exp. group					
1	Acute	Deviant	3:1	Obtuse	Non-deviant
2	Acute	Deviant	2:1	Obtuse	Non-deviant
3	Acute	Deviant	2:1	Obtuse	Non-deviant
4	Acute	Deviant	1.5:1	Obtuse	Non-deviant
5	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
6	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
7	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
Sham group					
1	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
2	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
3	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
4	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
5	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
6	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
Ref. group					
1	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
2	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
3	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
4	Obtuse	Non-deviant	1.5:1	Obtuse	Non-deviant
5	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
6	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant
7	Obtuse	Non-deviant	1:1	Obtuse	Non-deviant

sectioned (4 μm). Sections were stained with hematoxylin/eosin.

In 9 animals, 4 from the experimental group, 2 from the sham group, and 3 from the reference group, bilateral Scanning Electron Microscopic (SEM) analysis of the condyle articulating surface was performed. Each condyle was separated from the mandible with a fine-toothed saw, and after gentle rinsing of the surface with a jet of isotonic saline the specimen was dehydrated in ethanol and dried by liquid CO_2 according to the critical point drying technique (15) (Polaron E-3000 CPD). The dried specimen was mounted with electrically conductive glue (Agar Scientific Ltd., Stanstead, UK) on an aluminum specimen holder. It was coated with approximately 15 nm gold in a combined procedure of sputter coating (Edwards S150A Sputter Coater, Edwards High Vacuum Ltd., Crawley, UK) and in a modified evaporation system equipped with a modified tilting and rotation device (Edwards E12E214 Evaporation Unit, Edwards High Vacuum Ltd.). Microscopy was performed in a Cambridge Stereoscan 360 ixp SEM (LEO Electron Microscopy Ltd., Cambridge, UK), operated with a LaB_6 emitter, 15 kV and 0° tilt.

SEM micrographs were obtained as a surface survey at a magnification of ×19 and at a magnification of ×272 from three antero-posteriorly oriented zones of each condyle: a medial, a central, and a lateral zone. Approximately 10 micrographs of each zone covered the articulating surface (Fig. 3). All micrographs were given a localization code. Targets of interest were magnified to ×1360. Evaluation of surface morphology was made from prints. The surface was classified as (i) smooth with or without occasional fibrillations, (ii) smooth with even

Table 2. Histologic or scanning electron microscopic findings

Operated/right side		Non-operated/left side	
Exp. group		Exp. group	
1	Hyalinized (H*)	8	Hyalinized (H)
2	Fibrillations (SEM†)	9	No changes (SEM)
3	–	10	–
4	Hyalinized, more matrix (H)	11	No changes (H)
5	No changes (SEM)	12	Fibrillations (SEM)
6	No changes (SEM)	13	No changes (SEM)
7	No changes (H)	14	No changes (H)
Sham group		Sham group	
1	No changes (H)	7	Congenital defect (H)
2	No changes (H)	8	No changes (H)
3	Fibrillations (SEM)	9	No changes (SEM)
4	No changes (H)	10	No changes (H)
5	–	11	–
6	No changes (H)	12	No changes (H)
Ref. group		Ref. group	
1	No changes (H)	8	No changes (H)
2	–	9	–
3	No changes (H)	10	No changes (H)
4	No changes (H)	11	No changes (H)
5	No changes (H)	12	No changes (H)
6	No changes (SEM)	13	No changes (SEM)
7	–	14	–

*Histologic finding.
†Scanning electron microscopic finding.

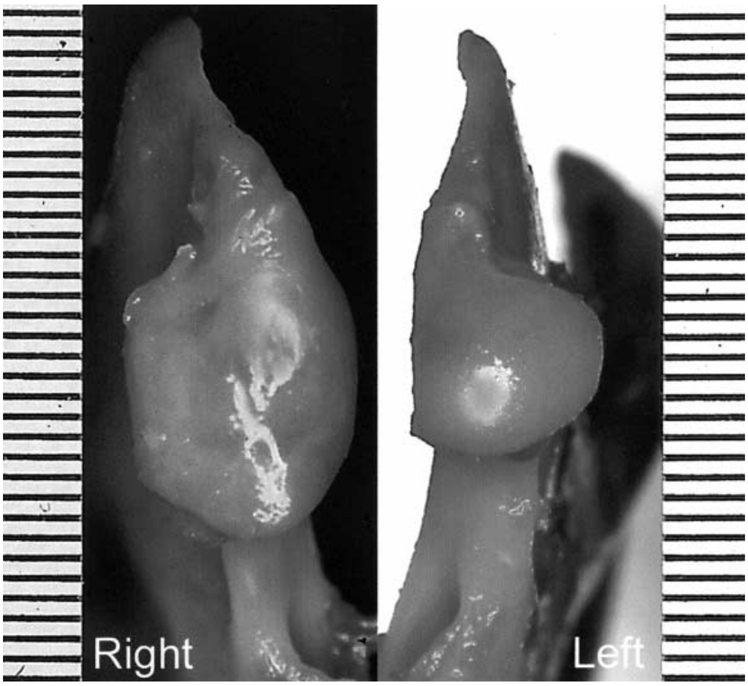

Fig. 4. Right, operated, and left, non-operated joint from 1 animal in the experimental group, seen in an axial view. The articulating surface of the condyle on the operated side is 2.2 times larger than the contralateral one.

distribution of fibrillations, and (iii) eroded. Due to technical failure, the final analysis included a total of 10 joints from 5 animals (Table 2).

Results

Macroscopic evaluation

Photographs of the articulating surfaces consistently showed smooth soft tissue coating without erosive changes in all of the 40 joints examined. Four condyles from disk displacement joints in the experimental group demonstrated deviation in shape. These 4 condyles were larger than all other condyles in an axial view and the articulating surface appeared bulgy. They were situated more inferiorly in relation to the rest of the mandibular ramus as compared to all other joints where the condyle articulating surface was seen most superiorly (Fig. 4) (Table 1). The size of the axially projected articular surface of the 4 enlarged condyles ranged from 31.5 to 44.1 mm^2. The projected size of the articulating surface of all 33 condyles from joints without disk displacement (12 from the sham group, 14 from the reference group, and 7 contralateral joints to the experimental joints) ranged from 11.2 to 21.5 mm^2. The articulating surface of the 4 enlarged condyles from the experimental group showed an acute angle in relation to a vertical line when studied in the lateral view. This resulted in a forward/downward rotation of the articulating surface

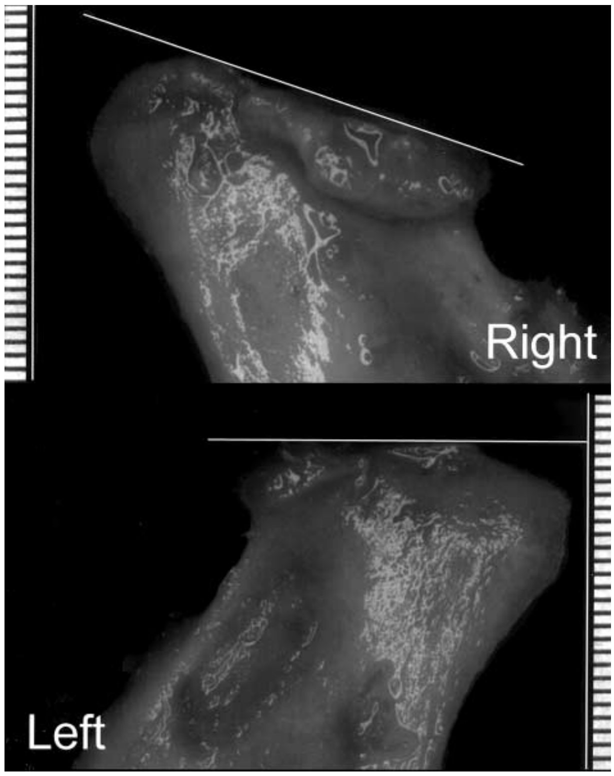

Fig. 5. Right and left joints from one animal in the experimental group, seen in a lateral view. Note the forward/downward rotation of the condyle surface on the operated side.

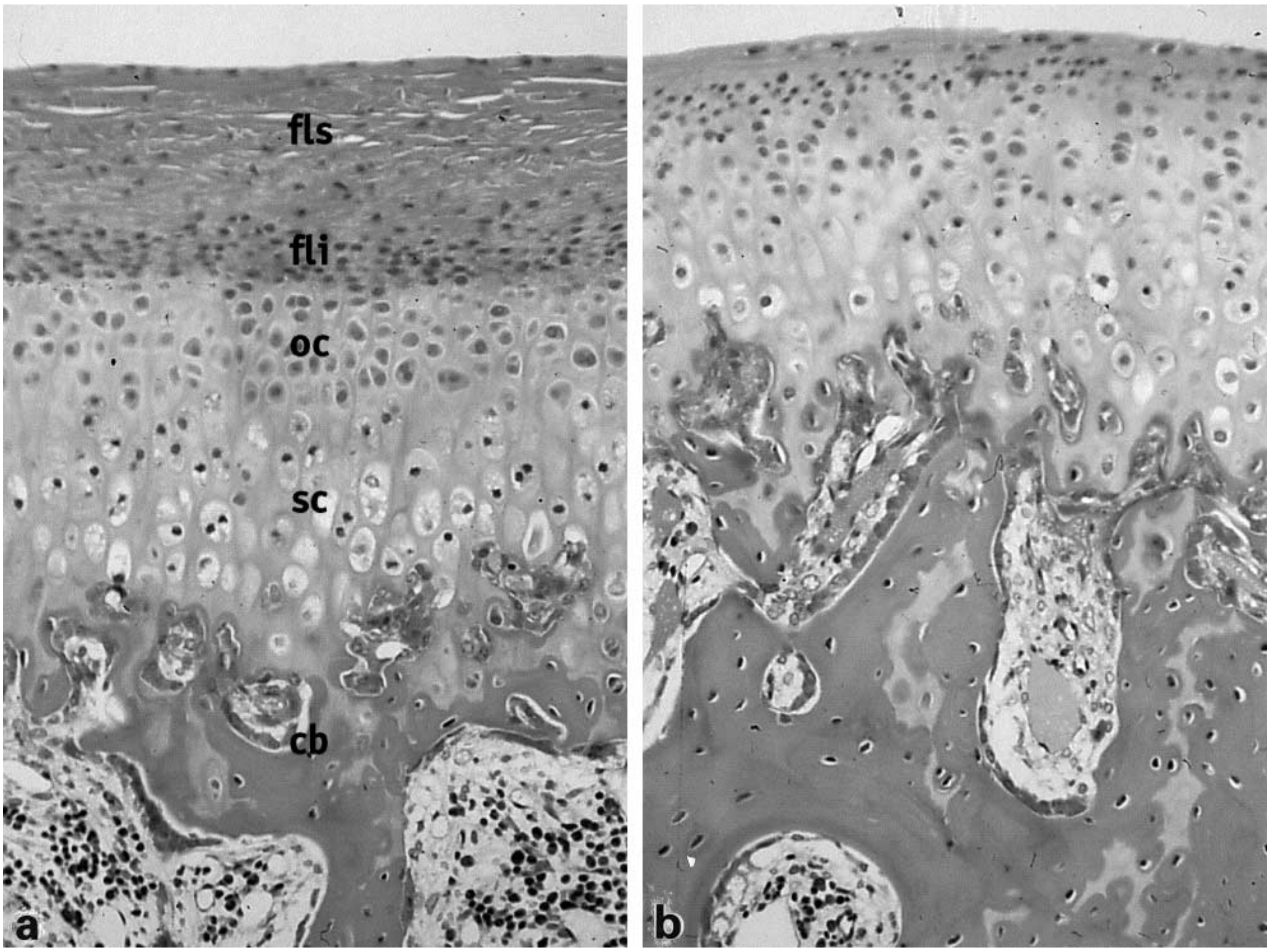

Fig. 6. (a) Histologic sagittal section of the posterior part of 1 condyle from the reference group. The different tissue layers are marked (fls = fibrous layer-superior stratum; fli = fibrous layer-inferior stratum; oc = ovoid chondrocytes; sc = spherical chondrocytes; cb = cancellous bone). (b) Anterior part of the same condyle. The superior stratum of the fibrous layer is thinner than in the posterior part.

(Fig. 5) (Table 1). The angle ranged between 54.5 and 85.0°. All condyles from joints without disk displacement demonstrated an obtuse angle in relation to the vertical line, ranging from 91.0 to 107.0°.

Microscopic evaluation

The 4 sham joints and 3 of their contralaterals, 2 non-operated joints in the experimental animals, and 1 out of 3 disk displacement joints demonstrated the same histological appearance as the 8 reference joints. Hence, 18/22 histologically examined condyles were covered with a fibrous connective tissue layer comprising 2 strata. The superficial stratum was thicker in the posterior part and gradually became thinner to eventually disappear in the anterior part. The inferior stratum showed cells with flattened nuclei lying parallel to the surface. This stratum also became thinner anteriorly where it was characterized by large amounts of matrix and appeared to form the outer surface of the condyle. Beneath the fibrous layer, a zone of larger ovoid chondrocytes was seen, followed by a zone of spherical chondrocytes in large lacunae with wide areas of partly calcified intercellular matrix. The spherical chondrocytes were arranged in more or less distinct columns and with occasional large amounts of intercellular matrix. The columnar zone blended with the underlying cancellous bone with a more or less irregular border between cartilage and bone (Fig. 6a–b) (Table 2).

Three condyles from the experimental group, 1 from a non-operated joint and 2 from operated joints, showed a deviation in histologic appearance compared with the description above. The 2 condyles from the operated joints also had an enlarged articulating surface with an acute angle to the vertical line. The surface of the fibrous connective tissue layer in all 3 condyles was hyalinized (Fig. 7) (Table 2). In addition, the posterior part of the condyle from the non-operated joint had an indistinct stratum with

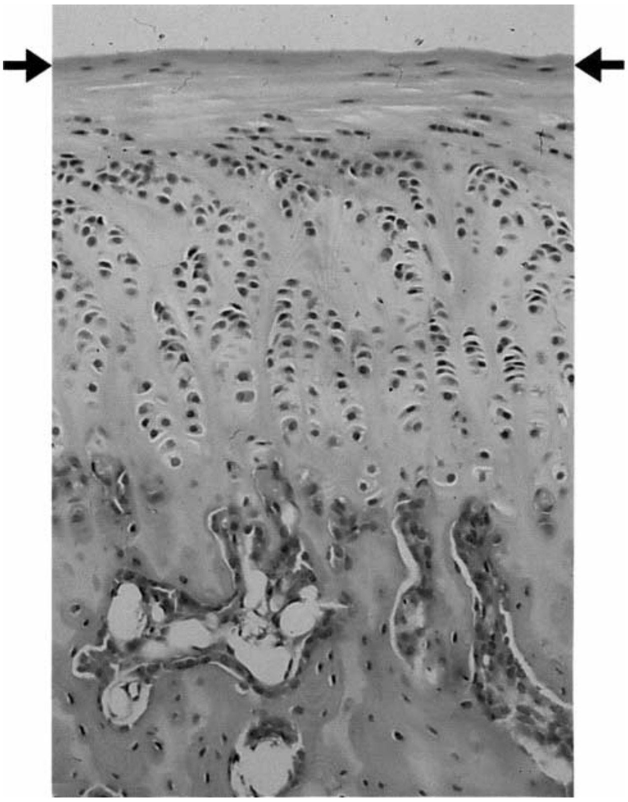

Fig. 7. Hyalinization (*arrows*) of the surface of the fibrous connective tissue layer in the articulating part of a condyle from an operated joint in the experimental group.

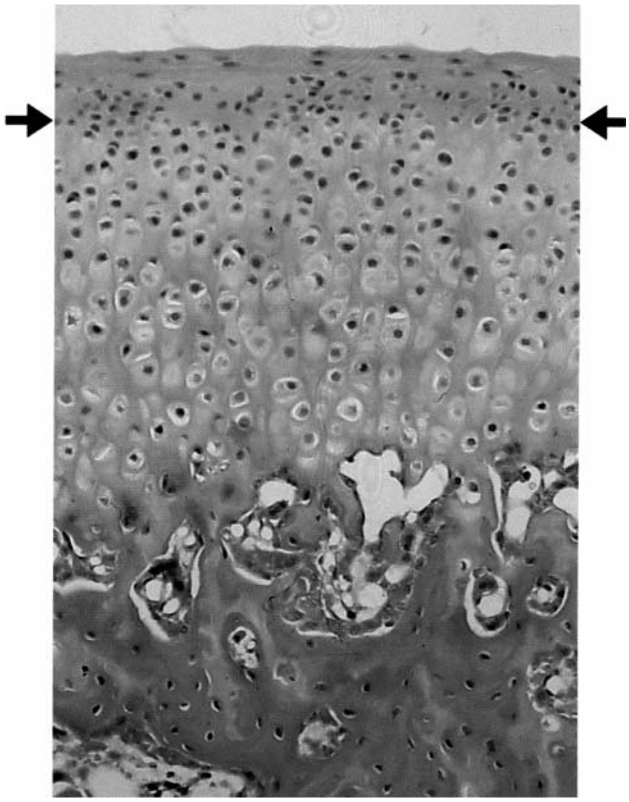

Fig. 8. The inferior stratum of the fibrous layer is indistinct (*arrows*) in the posterior part of a condyle from a non-operated joint in the experimental group.

flattened nuclei (Fig. 8). One condyle from an operated joint showed additional marked abnormalities in both the anterior and the posterior parts, with many areas revealing large amounts of matrix, lack of columnar arrangement, large spherical chondrocytes, and an accentuated irregular border zone between cartilage and bone (Fig. 9) (Table 2). A non-operated left condyle from 1 sham animal showed a central minor area with absence of chondrocytes and with an intact fibrous layer, indicating a congenital defect. The articulating surface was consistently intact in all condyles.

Nine of the 10 SEM-evaluated joints had a smooth and even articulating surface. In 1 joint with disk displacement the surface appeared bulgy at the low magnification of $\times 19$. Higher magnification ($\times 272$) revealed that the bulgy surface was covered by a smooth articulating soft tissue layer. This condyle was 1 of 4 condyles with an enlarged articulating surface with an acute inclination to the vertical line. Occasional fibrillations were found in all joints, mainly in the central and lateral parts of the articulating surface (Fig. 10).

Of the 241 micrographs from the 10 joints, 17 were classified to depict an even distribution of fibrillations (Fig. 11). Twelve of these 17 micrographs were from 1 condyle in a sham-operated joint. Three of the remaining 5 micrographs showed evenly distributed fibrillations on approximately 10% of the surface in a disk displacement joint with an acute angle of its enlarged but even articulating surface. The last 2 micrographs were seen in a left non-operated joint in an experimental animal, and covered less than 10% of the surface. The contralateral, operated joint in that animal did not have any detectable changes on its surface. The remaining 224 micrographs were classified as smooth with or without occasional fibrillations.

Discussion

Reduction of mandibular height secondary to TMJ disk displacement in growing rabbits has previously been attributed to a shortening of the condyle caused by loss of condyle mass due to degenerative changes (7). Besides causing loss of condyle mass, osteoarthrosis might also incapacitate the condyle growth layer, resulting in impaired growth (5). In both situations the cause of events would be: disk displacement, secondary degenerative tissue changes substantially affecting the bone, reduced mandibular height. The results of the present experimental study combined with the results from our previous studies

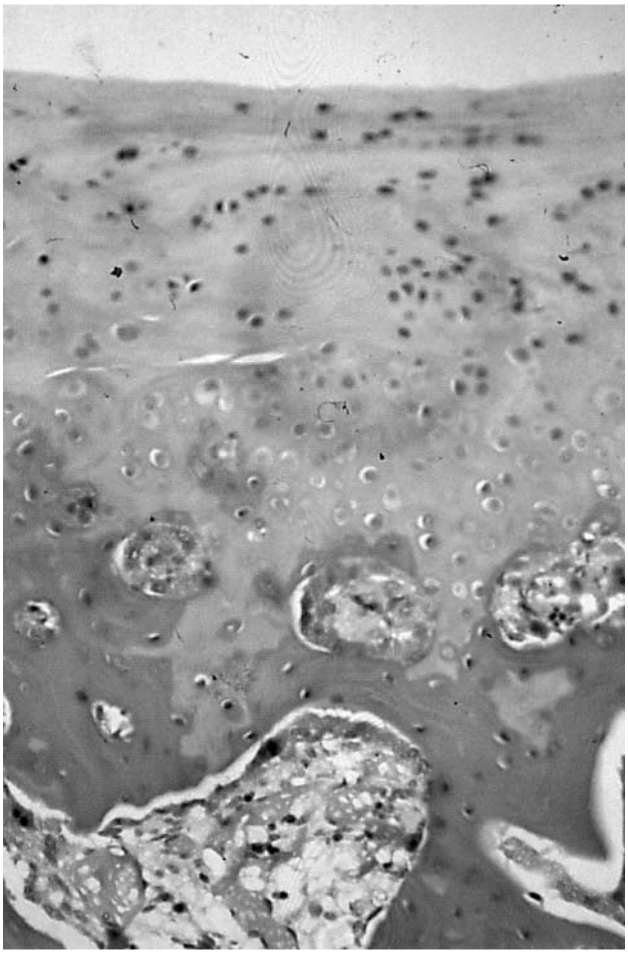

Fig. 9. Areas with large amounts of matrix are seen in the articulating part of a condyle from an operated joint in the experimental group.

of the same material (11, 12) have revealed that a reduction of ramal height and mandibular length in growing rabbits can be induced by disk displacement at a stage before degenerative changes have developed. This points to a primary adverse influence on mandibular growth.

TMJ disk displacement, as induced in the experimental animals in this study, implies a change in joint function, which can explain the adverse effect on mandibular growth, because changes in joint function are known to affect the growth of the condyle. Hence, infant monkeys quickly adapt to anterior condyle functioning with an increased thickness of the posterior condyle cartilage (16, 17) and posterior condyle growth through endochondral ossification (18). Retrusive forces to the mandible in infant monkey TMJs caused regressive condyle remodeling. These changes consisted of bone resorption of the posterior part of the condyle and the anterior aspect of the glenoid spine combined with bone apposition of the anterior part of the condyle. Thus retrusive force can cause a positional change of the condyle (18, 19). There is a preponderance for posterior functioning of the condyle in joints with an anteriorly displaced disk compared with joints with normal superior disk position (20). Hence, the faulty disk position might have influenced condyle growth in some of the experimental joints in this study by inducing posterior condyle functioning. Full elimination of joint function by intermaxillary fixation had no effect on condyle growth (21), supporting the conclusion that the induced growth changes reflect an adaptation to altered condyle function provided the condyle growth layer remains intact.

The surfaces of the 4 enlarged condyles in experimental joints with disk displacement were less convex. This would imply a decreased ratio between the true and the projected

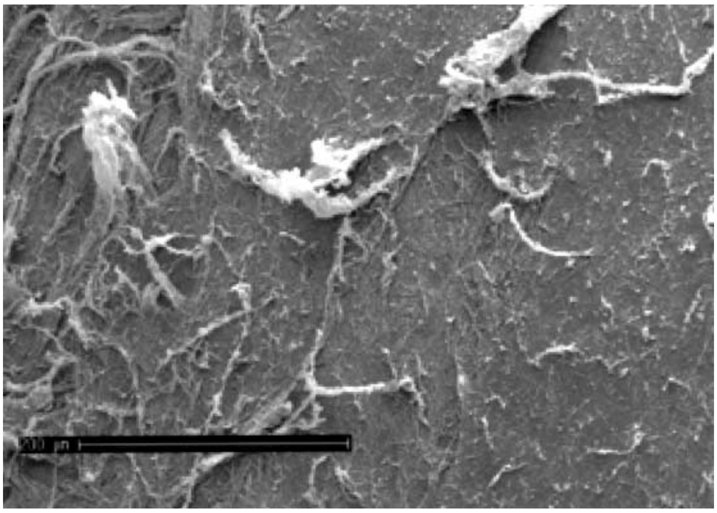

Fig. 10. Scanning electron micrograph with occasional fibrillations on the surface of the articulating part of a condyle from the reference group.

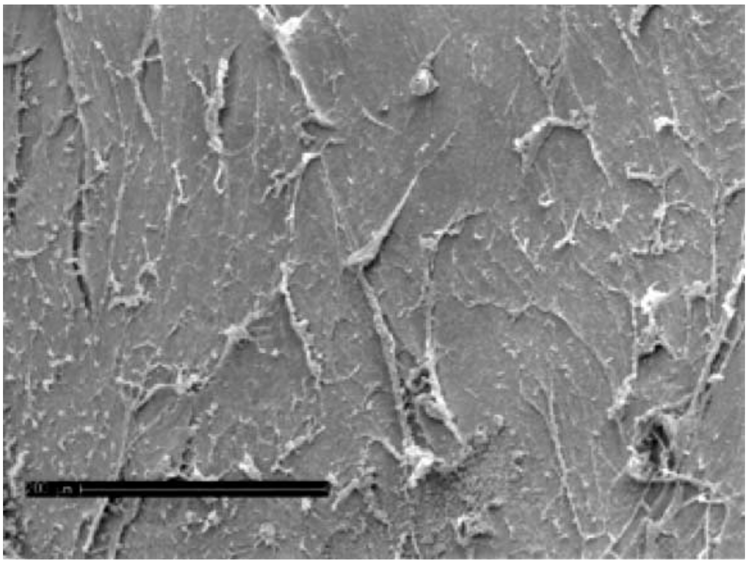

Fig. 11. Scanning electron micrograph with evenly distributed fibrillations on the surface of the articulating part of a condyle from a disk displacement joint in the experimental group.

articulating surface area in these condyles compared with the 33 condyles from joints without disk displacement. However, the 4 flattened surfaces were all bulgy, which increased the true surface area to a degree that was estimated to overcompensate the effect of loss of convexity. The accounted difference in projected size of the articulating surface between the 4 enlarged condyles and the remaining condyles is therefore likely to reflect an even larger true difference.

The condyle in 4 out of 7 joints with an experimentally displaced disk in this study demonstrated an enlargement and a deviation in shape of the articulating surface associated with an acute angle between the surface and the vertical. The angle in the remaining 3 experimental joints, all contralateral joints, the reference, and sham joints, was consistently obtuse. The surface enlargement and deviation in condyle shape was interpreted as an adaptation to fit the condyle surface to articulation against the fossa/eminence with no disk to take up the load in between. The change in angle of the articulating surface is likely to result from regressive remodeling as an answer to the pressure exerted by the displaced disk on the anterior aspect of the condyle at forward translation. A similar enlargement of the articulating surface in disk displacement joints, as seen in this study, was previously reported in adult rabbits (10). The surgical technique for displacing the disk, i.e. with the posterior attachment kept intact, was the same in both studies. A difference in results between studies was that the adult joints demonstrated erosions as signs of osteoarthrosis, while no such changes were present in the growing rabbits in this study. It is plausible that the explanation of the difference is to be found in a greater capacity for adaptation in the growing joint than in the adult joint. Unquestionably, the limit of capacity of tissue adaptation might eventually be surpassed also in the juvenile joint. It is probable that the hyalinization seen in 2 joints, additional large amounts of matrix in the fibrous layer in 1 joint, and the evenly distributed fibrillations found in 2 other joints are early indications of degenerative changes.

An individual variation in condyle size was observed in 1 reference animal. The shape of the large condyle was consistent with the other reference condyles and considered to be an anatomical variation. The disk displacement condyles with enlarged surface, on the contrary, deviated in shape from the contralateral condyles and are considered to be altered by regressive remodeling.

Changes in masticatory muscle function can affect the growth of both the coronoid and the condyle processes. Experimental elimination of temporal muscle function by detachment of the temporal tendon in growing rats inhibited the development of a coronoid process (22). Elongation of the coronoid process, on the contrary, can occur after mechanically induced mandibular hypomobility of both extra- and intra-articular origin (4, 5) presumably as a result of non-functional muscle activity caused by joint dysfunction. Hyperplasia of the coronoid process can also develop after condylectomy, probably secondary to an increased pull of the temporalis muscle that is not counterbalanced (23). Experimentally altered masticatory function after unilateral removal of occlusal contacts was shown to influence mandibular growth in rabbits (3). A shortening of ramal height was observed, suggestive of reduced condyle growth, although full mandibular height increased. The plausible explanation to these results, seeming contradictory, is that excessive bone growth at the gonion angle overshadowed the shortening of the mandibular ramus. Such growth pattern was previously revealed in the experimental animals included in this study, because metal implants permitted separate identification of ramal growth and growth of the mandibular body (11). Because TMJ disk displacement has been electromyographically demonstrated to trigger non-functional muscle activity on the ipsilateral side (24), such masticatory muscle dysfunction is likely to constitute a contributory factor to the impaired condyle growth in the experimental animals in this study with surgically created disk displacement.

Hence, there are indications that several factors can induce a change in mandibular growth, such as posterior restriction (16, 17) or extension of the condyle path within the articulating fossa (18, 19), mandibular hypomobility of intra- or extra-articular origin (4, 5), and masticatory muscle dysfunction (3, 23). Depending on presence or degree of interaction between factors, the effect on condyle growth is likely to vary. Such a variation probably explains why reduction of condyle growth was induced in all 7 experimental animals included in this study (11), although 3 condyles showed the same appearance as the 33 condyles from joints without disk displacement, while 4 condyles were enlarged and deviant in shape with a forward/downward rotation of an enlarged articulating surface.

The question arises regarding the relevance of the present findings on human TMJ. The rabbit joint is well suited for experimental studies of TMJ dysfunction because its capsule and the well-developed disk allow protruding and lateral sliding movements at mastication (25). The effect of mandibular hypomobility on the growth of the coronoid process and hyperplastic growth in the gonion angle has previously been shown to follow the same growth pattern in monkeys, rabbits and humans (4–7). It is therefore likely that the deviation in growth of the condyle process is also similar in rabbits and humans. Because TMJ disk displacement is a common TMJ affliction with a peak in incidence during puberty (26), the likelihood for its adverse impact on mandibular growth in teenagers must be further investigated.

TMJ disk displacement can induce reduction of mandibular height and length (11, 12). None of the condyles from joints with surgically created disk displacement demonstrated any osteoarthrotic changes on the articulating surface, but changes in condyle shape, angulation, and area of the articulating surface were observed, implying a primary adverse effect on condyle growth.

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