The effect of prenatally increased oxygen tension on the development of the mandibular condyle

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Twenty-four Long Evans/Turku rats were used to study the effect of prenatally increased oxygen tension on the mandibular condylar cartilage. Pregnant rats were exposed to increased oxygen tension in an air chamber for 14 days. The animals were returned to normal laboratory conditions after parturition. Three control and three experimental young rats were killed at the ages of 1, 5, 10, and 20 days for microscopic studies. Sagittal sections of the temporomandibular joint showed the cartilagenous condylar process to be narrower anteroposteriorly at 1, 5, 10, and 20 days postnatally, and it seemed to be bent backwards in experimental animals at the age of 1 day, in comparison with controls. The mesenchymal and chondroblast cell layers were thickened at the ages of 1, 5, 10, and 20 days. The findings indicate that prenatally increased oxygen tension increases the postnatal mesenchymal cell population and support the hypothesis that the size of the mandible is partly determined by the number of mesenchymal cells present during the prenatal phase. □ *Condylar cartilage; embryology; rats; structure*

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The condylar cartilage develops from the mesenchymal cell condensation, the condylar blastema. The proximal part of the cartilage is joined to the mandible by endochondral ossification (1–3). The distal portion of the process continues to grow, the main growth components being mesenchymal cells, which are the proliferating cells (4, 5), and hypertrophying cartilage cells, which are responsible for the expansive growth. During postnatal life the mesenchymal cells can be affected by environmental factors in vivo—for instance, by increased oxygen tension (T. Kantomaa. The effect of increased oxygen tension on the mandibular condylar cartilage. Unpublished observations.) The growth of the condylar cartilage, however, has been suggested to be more independent during prenatal life (6).

The purpose of this investigation was to examine the effect of increased oxygen tension during prenatal life on the growth of the condylar cartilage.

Materials and methods

Pregnant rats were exposed to increased oxygen tension for 14 days at 9 to 23 days of gestation. The animals were kept in an air chamber at 0.5 bar over the atmospheric pressure, and an air flow of 1 l/min containing 28% oxygen was passed through the chamber. The chamber was opened every other day so that the cages could be cleaned, and the food and water, which were available ad libitum, changed.

The experimental animals were kept under normal (laboratory) conditions after parturition, whereas the control animals were kept under normal conditions for the whole experimental period.

Three control and three experimental young rats were killed at the age of 1, 5, 10, and 20 days. The heads were fixed in neutral formalin and demineralized in 10% formic acid. Sagittal paraffin sections, 5 μm thick, from the temporomandibular joint were stained with hematoxylin and eosin or with toluidine blue.

Results

The animals tolerated the altered laboratory conditions well.

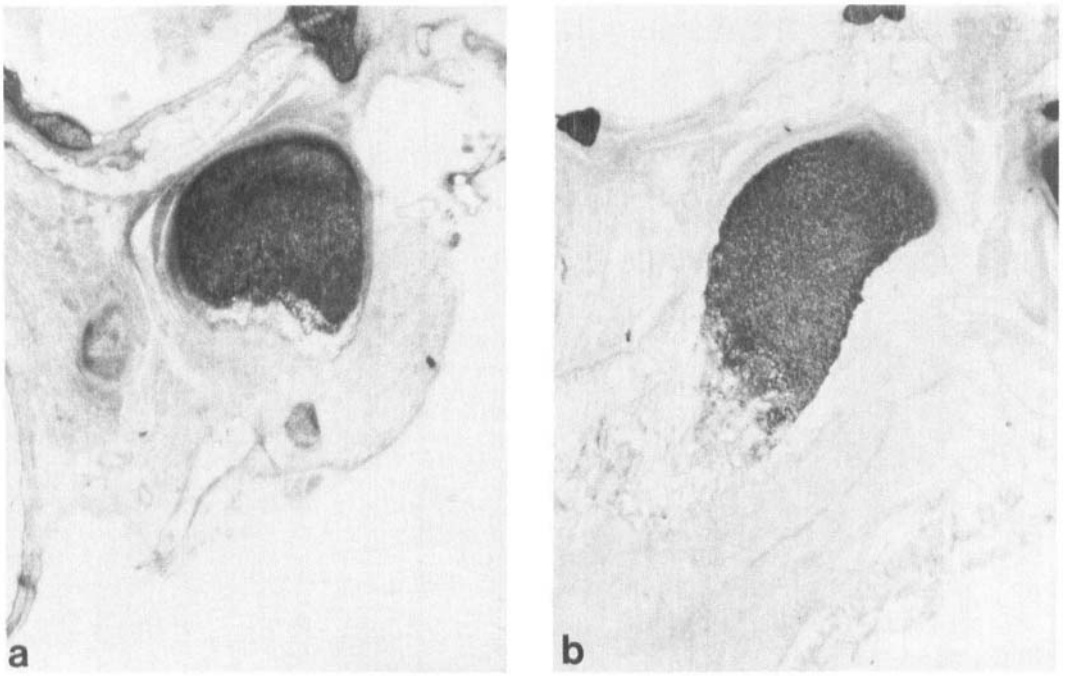

Fig. 1a. Sagittal section of the temporomandibular joint of a 1-day-old control rat. (Magnification, ×30.) 1b. Sagittal section of the temporomandibular joint of a 1-day-old experimental rat. The cartilagenous condylar process seems to be bent backwards, and the cell layers of the cartilage, especially the mesenchymal cell layer, are thickened. (Magnification, ×30.)

The condylar cartilage seemed narrower anteroposteriorly in experimental animals at the ages of 1, 5, and 10 days (Figs. 1 and 2). The cartilagenous condylar process seemed to be bent backwards at the age of 1 day (Fig. 1).

The mesenchymal cell layer, the chondroblast cell layer under the mesenchymal cells, and the layer of hypertrophied cartilage cells were markedly thickened at the ages of 1, 5, and 10 days (Figs. 1–4).

Discussion

It has been suggested that oxygen tension is one of the factors regulating the differentiation of the mesenchymal cells and the development of cartilage during embryogenesis (7). The elevated oxygen tension seems to diminish the glycosaminoglycan synthesis postnatally in the condylar cartilage in vivo (T. Kantomaa. The effect of increased oxygen tension on the mandibular condylar cartilage. Unpublished observations.) A similar effect was not observed in this experiment when oxygen tension was increased prenatally. Although the results seem to be at variance with earlier postulates about the role of oxygen in embryogenesis (8), it is possible that, in this experiment, the oxygen tension was not elevated enough to change the differentiation but that it was sufficient to increase the proliferation of the undifferentiated mesenchymal cells, which was found to occur to an even greater extent in this experiment than postnatally. This finding may support the assumption that the growth of the condyle prenatally is different from that in postnatal life (6). No disturbances analogous to those found during postnatal life (T. Kantomaa. The effect of increased oxygen tension of the mandibular

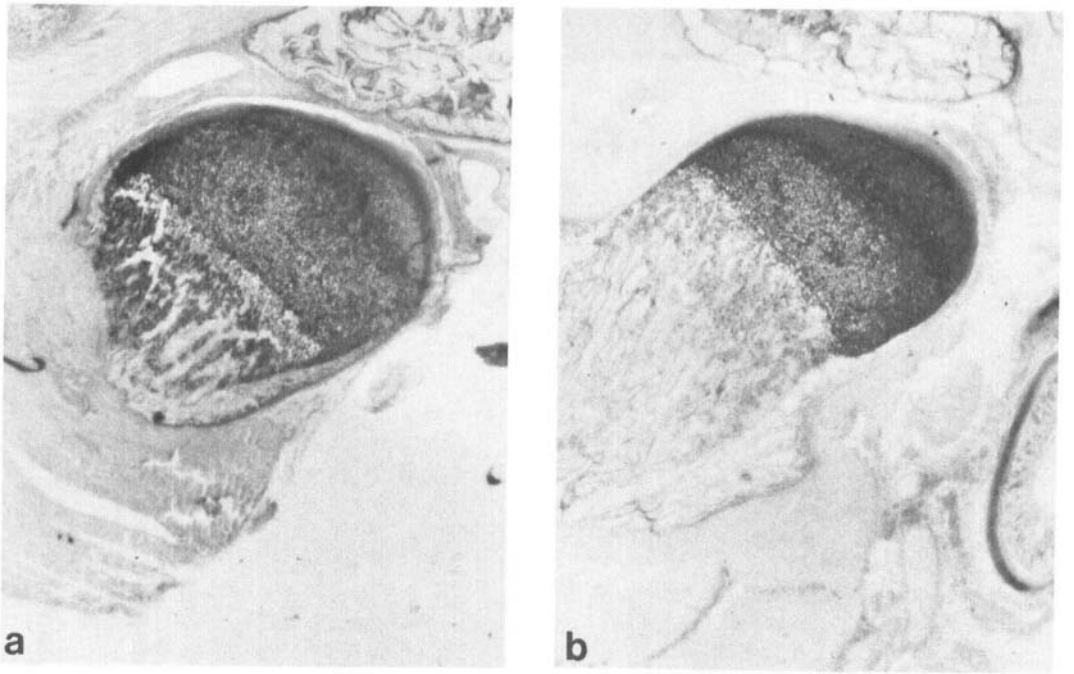

Fig. 2a. Sagittal section of the temporomandibular joint of a 5-day-old control rat. (Magnification, ×30.) 2b. Sagittal section of the temporomandibular joint of a 5-day-old experimental rat. The mesenchymal and chondroblast layers are still thicker than those in the control. (Magnification, ×30.)

condylar cartilage. Unpublished observations) were observed in the chondrogenesis after cessation of the oxygen treatment. However, the differences might also have resulted from the fact that the blood hemoglobin is high just after birth (at the age when the oxygen tension was decreased in this experiment) as compared with the situation of 25 days postnatally (T. Kantomaa. The effect of increased oxygen tension on the mandibular condylar cartilage. Unpublished observations.)

The mesenchymal cell layer was still thickened 20 days after cessation of the treatment. Increased oxygen tension seems to increase the mesenchymal cell population (T. Kantomaa. The effect of increased oxygen tension on the mandibular condylar cartilage. Unpublished observations.) Thus, although the proliferation might have continued at the same rate in control and experimental condyles after oxygen treatment, the difference remained, since the proliferating cell population was greater in the experimental condyles. This finding may be considered to support the opinion of Hall (9) that one of the factors regulating the size of the mandible postnatally is the number of mesenchymal cells present during embryonic life. To prove this would, however, require longer observation periods and biometry of dried skulls.

The reason for the bending of the cartilagenous condylar process remains obscure, and an histologic artifact cannot be ruled out. Provided that the bending is real, one possible explanation could be that the long cartilagenous process was bent under the pressure created by the increased growth of the cartilage against the fossa. The matter requires further study, however.

The increased hormone production may have resulted from the oxygen treatment, as the production of growth hormone and

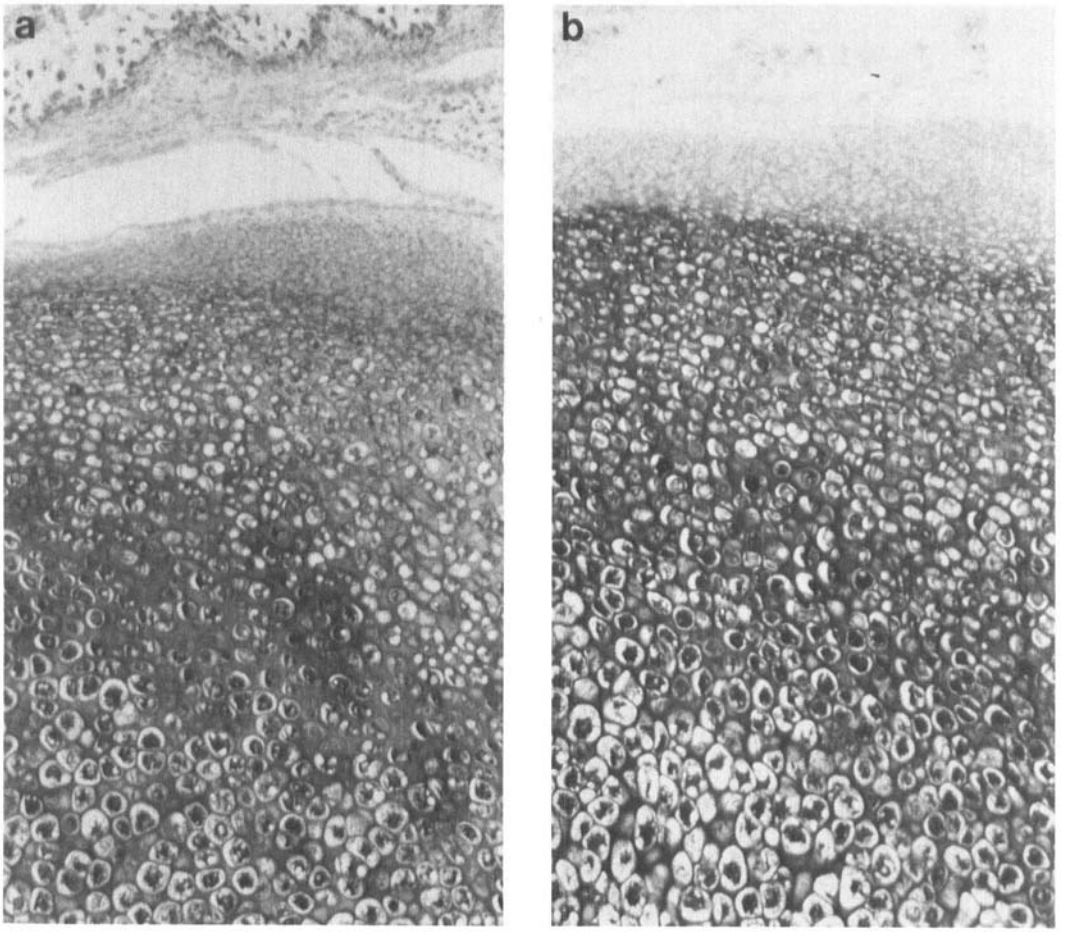

Fig. 3a. Higher magnification of the condylar cartilage of the 5-day-old control rat. (Magnification, ×200.) 3b. Higher magnification of the condylar cartilage of the 5-day-old experimental rat. The mesenchymal and chondroblast cell layers are greatly thickened. (Magnification, ×200.)

thyroxin diminishes under decreased oxygen tension (10). However, Hoskins & Asling (11) reported increased transversal width of the condylar process but could not find changes in the thickness of the whole cartilage after postnatal hormone treatment. These findings are the reverse of those obtained in the present experiments. Thus, the results seem to be due to the effect of increased oxygen tension at the local level rather than to increased hormone production.

In conclusion, the results of this experiment further support the earlier assumption (T. Kantomaa. The effect of increased oxygen tension on the mandibular condylar cartilage. Unpublished observations) that increased oxygen tension has a stimulating effect on the proliferating cells of the condylar cartilage. Return to normal laboratory conditions did not have the pathologic effect on mesenchymal cells which is observed postnatally (T. Kantomaa. The effect of increased oxygen tension on the mandibular condylar cartilage. Unpublished observations.)

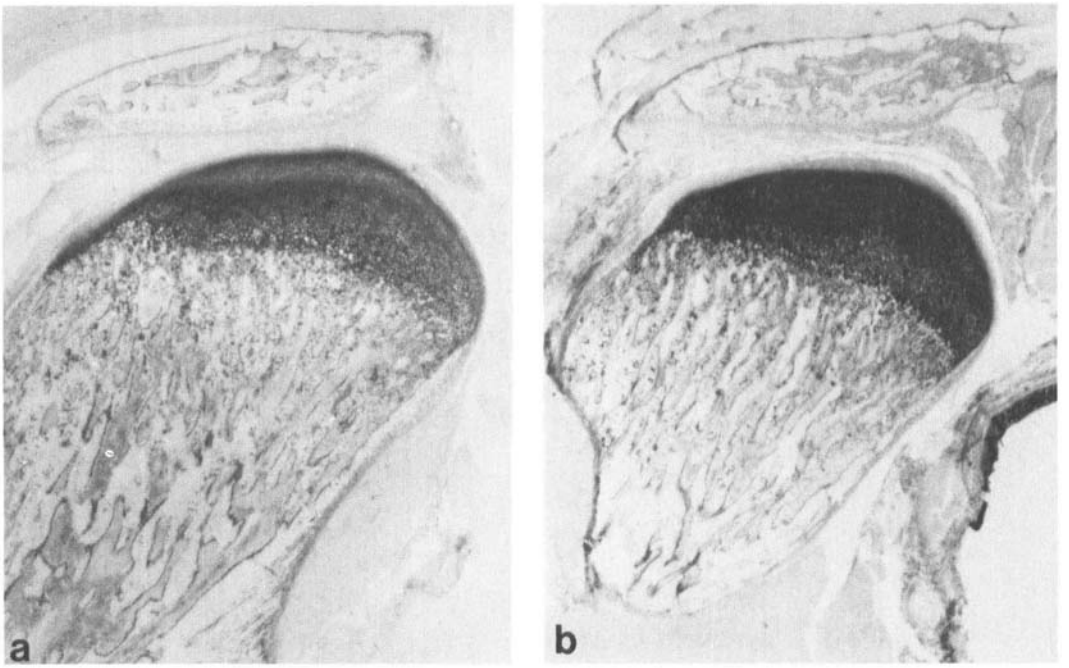

Fig. 4a. Sagittal section of the temporomandibular joint of a 20-day-old control rat. (Magnification, ×30.) 4b. Sagittal section of the temporomandibular joint of a 20-day-old experimental rat. The mesenchymal cell layer still appears to be thicker. (Magnification, ×30.)

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