

Effect of altered loading on condylar growth in the rat

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The aim of this investigation was to ascertain whether lessening of function by feeding rats a soft diet and cutting their incisors can change the growth of the condyle. Sixty Wistar rats were divided into two groups: a control group fed whole pellets and a soft-diet group fed ground pellets. At the age of 21 days the upper and lower incisors of the soft-diet group were shortened by cutting with a wire cutter twice a week. Ten control rats and 10 soft-diet rats were injected with alizarin red (200 mg/kg) intraperitoneally at the age of 22, 30, or 40 days and killed at the age of 30, 40, or 50 days, respectively. The heads were freed of soft tissues, and the growth of the condylar process and the mandible was measured. The height growth of the condylar process was significantly greater in the soft-diet group by 30 and 40 days, and its length growth was greater in the soft-diet group by 50 days. It is concluded that the change in the amount of chewing force and the place of articulation of the condyle alters the growth of the condylar process. Lessening of the load increases condylar growth until a new balance is achieved. □ *Growth; mandibular condyle; masticatory function; temporomandibular joint*

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It has been demonstrated by several investigators that the growth of the cartilage in the mandibular condyle is dependent on mechanical factors. Rats fed a soft diet have been shown to have a thinner layer of condylar cartilage (1), and condyles have been shown to be smaller (1, 2). Simon (3) cut the incisors of rats and concluded that compressive forces are necessary for condylar cartilage maturation, but Copray et al. (4) found in vitro that compressive forces can even have an inhibitory effect on the growth of the condylar cartilage, depending on the amount of force. Buchner (5) raised the bite in adult rats and concluded that lessening the load on the condyle provoked temporary activation of growth, the response being dependent on the age of the animal.

The aim of this investigation was to ascertain whether lessening of function by cutting the incisors and feeding rats a soft diet can alter the growth of the condyle at different ages.

Materials and methods

Forty male and 20 female Wistar rats were divided into 2 groups: a control group fed whole pellets (Hankkija Oy, Finland) and a soft-diet group fed ground pellets. Water was available ad libitum. At the age of 21 days, after they had been weaned, the upper and lower incisors of the soft-diet group were shortened by cutting with a wire cutter twice a week. Ten control rats and 10 soft-diet rats were injected with alizarin red (200 mg/kg (6)) intraperitoneally at the age of 22 days and killed at the age of 30 days; a further 10 female control rats and 10 female soft-diet rats were then injected at 30 days and 10 more control and soft-diet rats at the age of 40 days. These were all killed 10 days after the injection.

The heads were freed of soft tissues, and the measurements shown and explained in Fig. 1 were made.

The measurements were done twice, and

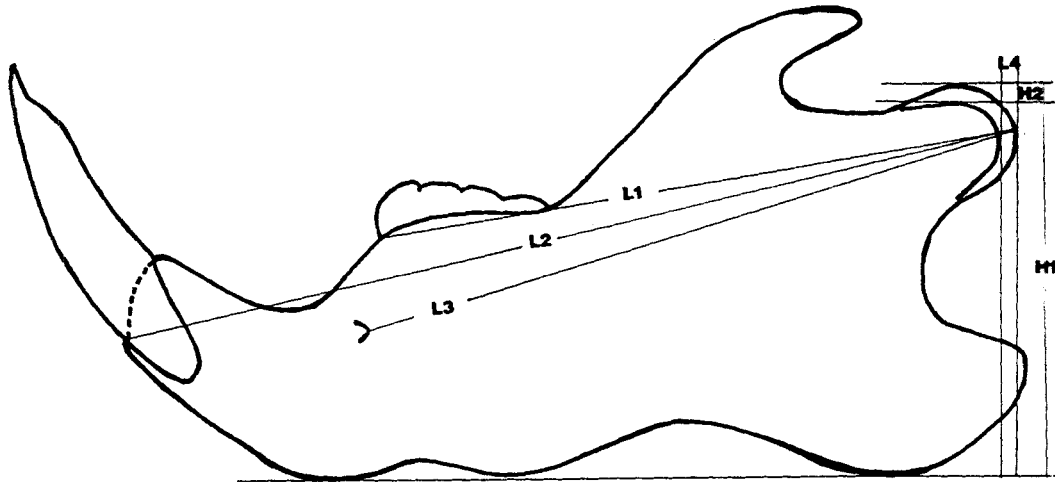


Fig. 1. Linear measurements made on the dry mandibular halves under the microscope. Distances L4 and H2 were measured under ultraviolet light. L1 = distance from the junction of the mesial surface of the first molar with the jaw bone to the extreme posterior point of the condyle; L2 = distance from the extreme anterior end of the jaw bone between the incisors to the extreme posterior point of the condyle; L3 = distance from the posterior rim of the mental foramen to the extreme posterior point of the condyle; L4 = distance between the extreme posterior point of the condyle and the alizarin red line parallel to the tangent to the inferior border of the mandible; H1 = distance from the extreme superior surface of the condyle to the inferior border of the mandible; H2 = distance between the most superior point of the condyle and the alizarin red line perpendicularly to the tangent to the inferior border of the mandible.

the intra-examiner error was calculated from the formula

$$s(i) = \sqrt{\frac{\sum d^2}{2n}},$$

where d is the difference between repeated measurements. The differences between the groups were tested with Student's t test for small samples.

Results

The methodologic error in the height growth measurements was 2.5% of the variance of the total sample, and that in the length growth measurements 7.6%.

The weight of the soft-diet rats was insignificantly but consistently less than that of the controls.

Visual inspection showed the condylar processes to be more tapered in shape in the control groups (Figs. 2 and 3).

The height growth of the condylar process

was significantly greater in the soft-diet groups except at 50 days. The length growth of the condylar process was greater in the soft-diet group at the age of 50 days and in the control group at the age of 40 days (Tables 1, 2, and 3).

To ascertain whether there are any differences in the growth of the condylar processes between the sexes, the length and height growth were also measured in female rats injected with alizarin red at age 40 days and killed at age 50 days. As in the males, the length growth of the condyle was significantly greater in the soft-diet group (difference, 0.2 mm; $p < 0.001$), and the height growth was the same in both.

Neither the total length nor the height of the mandible differed between the groups (Tables 1, 2, and 3).

Discussion

Various animal models have been used to

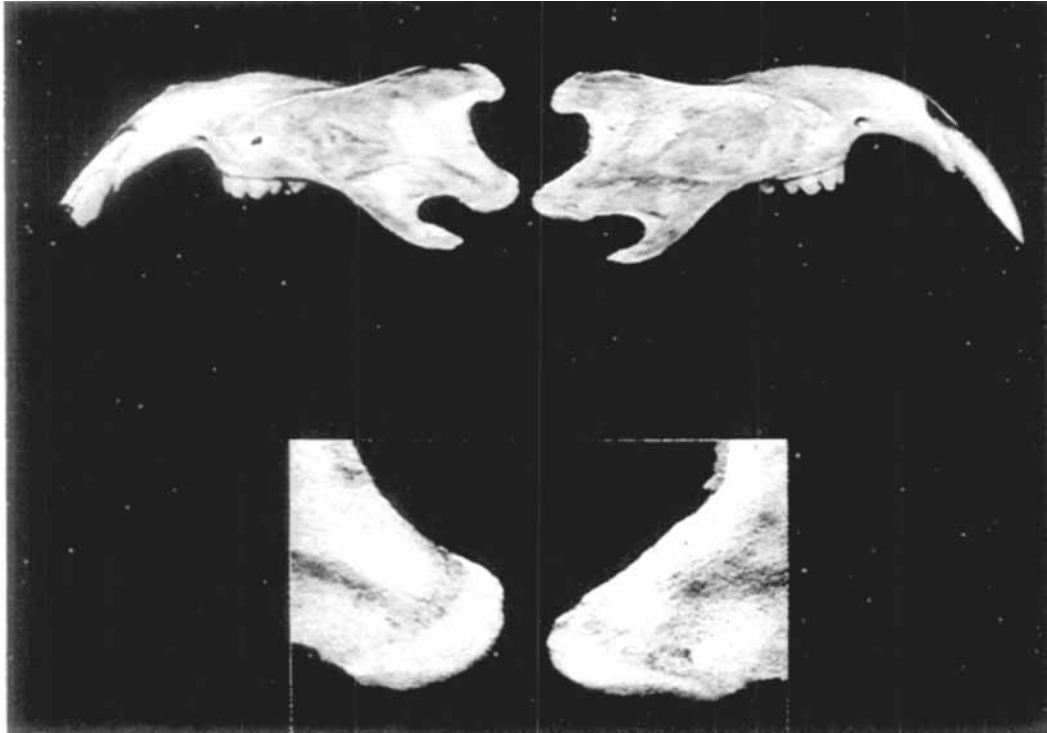


Fig. 2. Mandibular halves from 30-day-old rats. The growth in the height of the condyle in an experimental rat (right) after the injection of alizarin red has been greater than that in a control rat (left).

investigate the role of mechanical factors in the growth of condylar cartilage. To lessen the loading on the condyle, the animals have been fed a soft diet and their incisors cut (3, 7), the bite has been raised with a splint (5), or the articulating area of the condyle on the articular surface of the glenoid fossa has been changed by forcing the mandible forwards or backwards (8, 9) or by cutting the incisors (7). Alternatively, the effects of the duration, magnitude, and frequency of the force have been studied in an organ culture system (4). The soft diet used in this experiment obviously reduced forces exerted on the mandibular condyle during mastication. The position of the condyle in the fossa differs between mastication and incision in rodents, the lower jaw protruding during incision while the condyle occupies a more posterior position on the flat articular surface during mastication (10). Cutting of

the incisors lessens the protrusion of the mandible, and the loading on the anterior part of the articulating surface decreases (7).

The growth of the condylar cartilage has been studied by measuring the dimensions of a mandible (1, 11) or evaluating the changes in condylar cartilage metabolism (7, 12). In this experiment the growth of the condyle was observed by means of vital staining, which gave us the opportunity to evaluate specifically the changes in the growth of the condylar process. The dose level of alizarin red injected here does not have any inhibitory effect on the growth of bone in experimental animals (6).

Kantomaa et al. (13) suggest that normal functioning may suppress the growth of the cartilage when a rat is changing its diet from milk to hard pellets as a part of weaning, and Copray et al. (4) found in vitro that the growth is reactivated on removing or reduc-

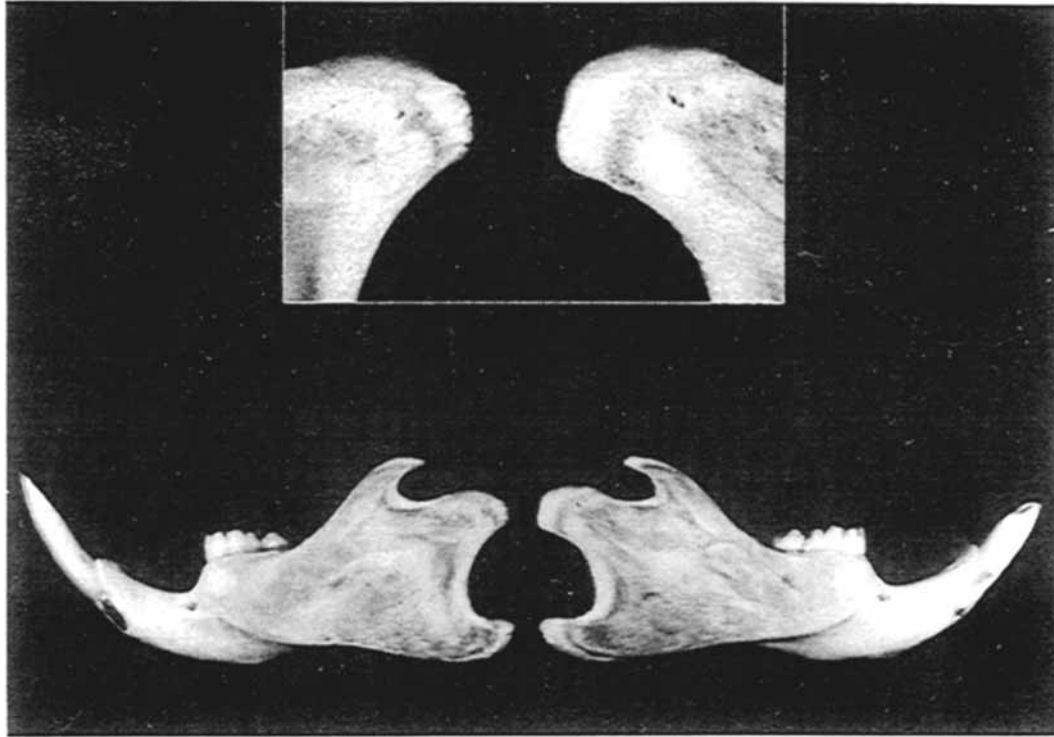


Fig. 3. Mandibular halves from 50-day-old rats. The growth in the length of the condyle in an experimental rat (right) after the injection of alizarin red is seen to be greater than that in a control rat (left).

ing the growth-restricting compression until a new balance was achieved. An analogous phenomenon might explain the results obtained here. The growth in the height of the condyles of the soft-diet animals increased, implying that a reduction in load

increases the growth of the condylar process. Hinton (12) suggests, however, that both matrix synthesis and proliferative activity are reduced in situations of decreased loading of the condylar cartilage.

The increased growth of the condylar pro-

Table 1. Measurements performed on the mandibles of the 30-day-old control and soft-diet rats, in millimeters

| Variable | Control | | Soft diet | | Diff. |
|----------|-----------|------|-----------|------|---------|
| | \bar{x} | SD | \bar{x} | SD | |
| L1 | 14.5 | 0.44 | 14.2 | 0.60 | -0.3 NS |
| L2 | 18.7 | 0.49 | 18.3 | 0.45 | -0.4* |
| L3 | 15.4 | 0.54 | 15.0 | 0.31 | -0.4* |
| L4 | 0.7 | 0.51 | 0.7 | 0.10 | 0.0 NS |
| H1 | 7.4 | 0.25 | 7.4 | 0.67 | 0.0 NS |
| H2 | 0.3 | 0.09 | 0.6 | 0.11 | 0.3*** |

*** $p < 0.001$; * $p < 0.05$.

Table 2. Measurements performed on the mandibles of the 40-day-old control and soft-diet rats, in millimeters

| Variable | Control | | Soft diet | | Diff. |
|----------|-----------|------|-----------|------|--------|
| | \bar{x} | SD | \bar{x} | SD | |
| L1 | 15.8 | 0.28 | 15.8 | 0.27 | 0.0 NS |
| L2 | 20.3 | 0.45 | 20.3 | 0.34 | 0.0 NS |
| L3 | 16.7 | 0.28 | 16.7 | 0.32 | 0.0 NS |
| L4 | 0.7 | 0.12 | 0.5 | 0.10 | -0.2** |
| H1 | 9.0 | 0.37 | 8.7 | 0.23 | -0.3* |
| H2 | 0.5 | 0.11 | 0.7 | 0.06 | 0.2** |

** $p < 0.01$; * $p < 0.05$

Table 3. Measurements performed on the mandibles of the 50-day-old control and soft-diet rats, in millimeters

| Variable | Control | | Soft diet | | Diff. |
|----------|-----------|------|-----------|------|--------|
| | \bar{x} | SD | \bar{x} | SD | |
| L1 | 16.8 | 0.62 | 16.8 | 0.28 | 0.0 NS |
| L2 | 21.5 | 0.68 | 21.7 | 0.22 | 0.2 NS |
| L3 | 17.9 | 0.69 | 17.9 | 0.25 | 0.0 NS |
| L4 | 0.6 | 0.10 | 0.8 | 0.09 | 0.2** |
| H1 | 9.8 | 0.51 | 9.8 | 0.27 | 0.0 NS |
| H2 | 0.4 | 0.11 | 0.5 | 0.10 | 0.1 NS |

** $p < 0.01$.

cess between 22 and 50 days in the animals fed a soft diet could also be a result of accelerated usage of the mesenchymal and cartilage cells for endochondral ossification. It has been shown that the thickness of the cell layers in the mandibular condylar cartilage diminishes when masticatory function is lessened (1, 3, 7), and it has been shown recently that maturation is also accelerated (Kantomaa et al., unpublished observation). Enhanced hypertrophy of the mesenchymal cells and the following endochondral ossification would produce more bone, but it must be remembered that the number of mesenchymal cells available for future growth is reduced.

It has been postulated that the posterior region of the condylar cartilage may be the load-bearing region during incision (10). This would explain the greater length growth of the condyle in the experimental group at the age of 50 days, since the soft diet and incisor cutting reduced the loading of the posterior region of the condyle (7). Interpretation of the results with regard to length growth is further confused, however, by the finding that it was reduced in the soft-diet group at 40 days, although all the other measurements and those made at all other ages showed the soft-diet animals to grow more.

It is significant here that the size of the whole mandible did not differ between the groups. Other investigators have also shown that the effect of dietary consistency on the final size of the mandible is minimal (1, 11).

The increased growth in the height of the condylar process is probably masked by lessened growth in the lower border of the mandible, where a decrease in muscle function has been shown to lessen appositional growth (14). This opposite reaction of the growth of the condylar and angular processes to changes in the amount of mechanical loading is not in line with the findings of Duterloo & Wolters (15) that condylar cartilage can be replaced by angular cartilage. Their findings and those of the present investigation indicate that while these cartilages are similar, the mechanical load exerted on the angular and condylar cartilages during mastication must differ.

In conclusion, the results of this experiment indicate that a change in the amount of force and the place of articulation of the condyle will alter the growth of the condylar process. Lessening the loading increases the growth of the condyle until a new balance is achieved.

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